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THE PRODUCT DATA EXCHANGE STANDARD (PDES)

PRESENTED TO:

FEDERAL COMPUTER CONFERENCE

SPECIAL THEME TRACK: TYING IT ALL TOGETHER

STANDARDS FOR A PAPERLESS WORLD

SEPTEMBER 9, 1985

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CHAIRMAN, PDES LOGICAL LAYER INITIATION TASK

PDES SCOPE AND OBJECTIVES

PDES stands for Product Data Exchange Standard. A long-term project, chaired by Kalman Brauner of The Boeing Company, currently exists within the IGES Committee to develop PDES. This project has two primary objectives:

1. to develop an exchange standard for product data in support of industrial automation

2. to represent the US position in the International Standards Organization (ISO) arena relative to the development of a single worldwide standard for the exchange of product data

A new standard is being developed out of the belief that no existing standard can be extended to support industrial automation sufficiently well.

"Product Data" is taken to be more general than "product definition data". It includes data relevant to the entire life cycle of a product: manufacturing, quality assurance, testing, support, etc. Industrial product areas supported in previous exchange standards work within the IGES Committee include mechanical, electrical, plant design, and AEC. While there is no inherent limitation in the PDES scope to these areas, it is naturally to be expected that these areas will be among the first to be addressed within PDES.

Development of an exchange standard for product data involves settling on a set of logical structures to contain the product data information, and also settling on the manner in which these structures will be implemented in computer form.

The ISO Technical Committee TC 184 (Industrial Automation Systems) and its Subcommittee SC5 (External Representation Of Product Model Data) are relatively new committees within ISO, SC4 having first met in July, 1984. The US has the Secretariat for this Subcommittee. Brad Smith of the National Bureau Of Standards, is Chairman (as well as being IGES Chairman). Since that first meeting, events have moved quickly. There is agreement within the Subcommittee that a single worldwide standard for the exchange of product data is needed. The goal of the standard is "...the capture of information comprising a computerized product model in a neutral form...throughout the life cycle of the product". The name of the standard is to be STEP - Standard for the Transfer and Exchange of Product Model Data. Technical work for future versions of the standard will be accomplished by existing and future national projects. Technical specification for the first version of the standard is targeted for December 31, 1986, with effective industrial use targeted for 1990.

It is the US intention that PDES and STEP will be identical. At its June, 1985 meeting, the IGES Steering Committee unanimously passed a resolution that the PDES project should represent US interests in the STEP effort. Since that time, the US TAG has requested that the PDES project adopt both the recently drafted set of detailed technical requirements for STEP, and also its list of contents for Version 1.0. Because of the history of very active involvement by large numbers of people within the IGES Committee, it is expected that the PDES project will assume the leadership position in the STEP development. Participating countries to this date, besides the US, include: Canada, Germany, Switzerland, and the United Kingdom. Japan is expected to become active soon, and has already sent representatives to a Working Group meeting held in this country.

THE PDES RELATIONSHIP TO IGES AND ITS DATA EXCHANGE HERITAGE

The June 1985 meeting of the IGES Steering Committee also outlined the relationship that is to exist between the IGES and the PDES specifications. Work within IGES Technical Committees will simultaneously be directed toward future, upward compatible versions of IGES and also toward a draft initial version of PDES. IGES Version 3.0 is now in final editorial review. The draft version of PDES is to be, at a minumum, functionally equivalent to the then-current version of IGES, perhaps Version 4.0. PDES need not be directly upwardly compatible with IGES, but must accommodate a conversion path. When this functional equivalence exists, development efforts will be directed toward PDES, with maintainence efforts being directed toward IGES. It is intended that this take place by December 31, 1986. An IGES Long Range Plan, now in draft, will further explain this relationship and other topics as well, such as test methodology and committee structure.

Other data exchange efforts besides IGES Version 4.0 will affect PDES in one way or another. In broad terms, the legacy of some of these other efforts is as follows: The IGES efforts form one "tier", or logical grouping, of efforts. These have data exchange between dissimilar interactive graphics CAD/CAM systems as their driving force. Early versions were implicitly targeted toward systems of the 70's and early 80's, and toward mechanical applications. Thus, from the start, 2D drawings, 3D wireframe models, and certain generative type surfaces were emphasized. With the exception of those entities expressly intended for the drawing application area (eg., linear dimension, angular dimension, general note, etc.), most entities were generic (eg., line, arc, composite curve, associativity), so that the intent of the exchanged data had to be imposed from outside the data itself. Typically, this would involve a human viewing a representation of the data on a graphics system, keying off such things as geometric shape or placement relative to the part itself. Thus,the early versions of IGES were intended for human oriented interpretation of the data rather than for automated interpretation and use of the data.

In addition to additional geometry entities, later versions of IGES did include application specific entities in the Electrical, FEM, and Plant Design areas. However, processors which read and produce these entities have yet to see extensive use.

A second tier of efforts consists of the CAM-I XBF-2 effort, the IGES ESP effort, the ICAM PDDI effort, and the follow-on GMAP effort sponsored by the Air Force CIM Program. (These acronyms denote, respectively, Computer-Aided Manufacturing-International, Inc.; Experimental Boundary File-2; Initial Graphics Exchange Specification; Experimental Solids Proposal; Integrated Computer Aided Manufacturing; Product Definition Data Interface; Geometric Modelling Applications Interface Program; Computer

Integrated Manufacturing.)

These efforts between them bring two innovations to the fore, and in effect usher in a more modern product data exchange era. The first innovation is the emphasis on a more complete definition of the shape of a part - that is, the emphasis on solid modelling, in which the set of spatial points occupied by an object is completely determined. In addition to this complete "quantitative" description of an object, some systems also provide a "qualitative" description by decomposing the object into topological entities such as faces, edges, and vertices which describe the connectivity of the part. These two types of descriptions are then related by having the topological entities indicate which geometry entities are needed for their definition.

> [Both the CAM-I XBF-2 and the IGES ESP work included entities for boundary and CSG representation of solid objects, as well as topological entities. The PDDI work, for which McDonnell Douglas was the prime contractor, included entities for boundary representation and for topology. The PDDI project had as its purpose the development of a product model and a data exchange format capable of conveying sufficient design information to manufacture a part. Four types of aerospace parts were examined. Final demonstrations for this three year contract are now being conducted. A follow-on effort sponsored by the Air Force CIM Program to extend the PDDI work is the Geometric Modeling Applications Interface Program. This effort is comparable in spirit but larger in size than the PDDI effort, and will be starting soon. Two new classes of parts, and applications throughout the product life cycle such as design, analysis, inspection, and product support will be considered. The new part classes are turbine blades and disks. The effort will also emphasize exchange of geometric modelling information between these applications, taking it as a given that many different geometric modelling techniques are used across the various applications areas.]

The PDDI project went a bit further than just geometry and topology entities, identifying entities for other higher level qualitative structures called part or form "features". Features allow high-level concept communication about parts. Examples are hole, flange, thread, web, pocket, chamfer, etc. The PDDI feature entities relate specific topology and geometry entities to a given feature so that identifying information for that feature can be explicit in the data, a necessary condition for the support of automation.

Geometry, topology, and feature information are often collectively referred to as "shape information".

The other innovation from this class of data exchange efforts, in fact, from the PDDI and the GMAP efforts, is the emphasis on having the computerized part model be a "complete" model. This means that the model contains all necessary shape and non-shape information sufficient to accomplish a given function; that the information is in a suitable, i.e., automation-enabling, computer form; and, that the different types of information are associated as required. For example, tolerance information would be carried in a form directly interpretable by a computer rather than in a computerized text form intended primarily for interpretation by a human, and, this information would be associated with those entities in the model affected by the tolerance. Other non-shape entities include administrative entities having to do with such things as effectivity, specifications, material, notes, etc. Thus, the general notion associated with a complete part model is that it obviates the use of human-oriented drawings and other paper documents as a necessary means of passing information between different functions.

It is interesting to note that the first tier of efforts are all standards efforts, concerning themselves with existing systems and techniques, while the second tier of efforts are research and development projects concerning themselves with finding out how things should be, and ultimately intending to effect change.

THE CONTENT EMPHASIS OF PDES

The PDES effort will reflect this dual heritage, and will extend it. It is intended that the PDES effort will also have a proactive influence on both users and vendors.

PDES will accommodate the wireframe models, the familiar generative surfaces, and the drawing representations as in the efforts in the standards class. But the driving force of PDES will be the accommodation of solids modelling and a complete product model, as is characteristic of the efforts in the research and development class. The spirit of PDES will be to accommodate in a computer-sensible, functional, integrated form, all of the types of information necessary to perform a given application.

In some cases, we will have to look to PDES technical working committees to define and relate the necessary information. In other cases, such as for the CAM-I and the PDDI efforts, and hopefully the GMAP effort, formally documented results will be made available to the PDES committees, or at least there will be a carryover of manpower. Such results would be examined within PDES, and could be expected to be modified and/or extended in order to achieve a consensus view.

PDES will extend the heritage from the standards efforts and the research and development efforts by providing a means for an organization to communicate its product breakdown structure. This implies accommodating such notions as part, subassembly, assembly, version, effectivity, release, etc., and also accommodating the natural correspondence between these kinds of items and the configuration documents, test data, change directives, etc., that pertain to these items. Many questions remain to be answered here. For example, a way must be found to relate the product breakdown structure to the PDES file or files representing that product (as when a model has to be spread over several files, or several models are contained in one file), and to do this in a way that will serve diverse companies that have diverse needs in this area.

THE PDES METHODOLOGY AND ITS CHALLENGES

The distinguishing characteristics of the PDES methodology reflect recent developments in data base and information systems in general. They also reflect techniques used and experience gained in other data exchange efforts. The PDES methodology is significantly different from the IGES methodology.

The PDES methodology involves: a three-layer architecture similar to the three-schema framework for data base management systems as identified by ANSI/X3/SPARC; reference models; formal languages; and coordination with other standards efforts.

Three-layer Architecture

The three-layer architecture is similar to the three-schema framework in which external, conceptual, and internal schemas are identified. In that framework, the conceptual schema comprises the unique central description, from the standpoint of the enterprise, of the meaning of the data, and the relationships among, and constraints upon, the data. It embodies the "rules of the business". This description is computer independent, i.e., it is conceptual. The external schema represents the manner in which individual users and applications need to view the data represented by the conceptual schema. Each external schema can therefore be derived from the one conceptual schema. The internal schema represents the actual physical computer storage structure being used to store and access the data.

Within PDES, the three layers corresponding to these three schemata are the logical layer, the application layer, and the physical layer.

The application layer will contain the descriptions and combinations of information peculiar to various application areas. Information modelling techniques (or, data modelling techniques, as they may sometimes be called) will be used to formally express what the required pieces of information and their relationships are for a given application area. These models are examples of what are termed "reference models". (Several application area reference models have been produced as part of current PDES proof of concept work, described in more detail in a later section. In that work, both the ICAM IDEF1 and the Nijessen Information Analysis Model (NIAM) information modelling techniques have been used.)

This layer will be supported by application subgroups such as the standing subcommittees now in IGES: Advanced Geometry, Electrical, Mechanical, AEC, FEM, Drafting, etc. The challenge here will be to actually do the modelling, then to manage the networking of the models into "clusters" depending on the product under consideration. Consistency and sufficiency within each cluster must be insured. The modelling itself will be a challenge because the application of information modelling techniques to production artifacts seems to be a new area.

The purpose of the logical layer is to provide a consistent, compter-independent description of the data constructs that will contain the information to be exchanged. Both generic and application-specific constructs are expected to be identified. The central challenge here, and perhaps in the entire PDES effort, will be to devise and carry out a conceptualization and integration methodology by which a minimally redundant set of generic data structures and relationships can be produced. That is, this set must be as lean as possible, and at the same time sufficient to support the wide range of applications. Some experience will be needed to be able to settle on such a methodology, but it will likely be a combination of a bottom-up approach (i.e., abstracting from information about individual application areas) and a top-down approach (i.e., deducing needed structures and relationships starting from some global classification schema for product data). Another challenge will be to build into the methodology the flexibility of being able to consistently extend the schema to accommodate new applications. Establishing modelling technique requirements is also expected to be challenging.

The physical layer corresponds to the internal schema and will be concerned with the data structures and data formats for the exchange file itself. The main challenge here will be to establish and maintain efficiency in such areas as file size and processing time.

Reference Models

A reference model for some universe of discourse is a model that collects together the necessary pieces of information and also their relationships to each other. The notion includes some mechanism, usually graphical, for describing the pieces of information and the relationships.

Reference models will be used throughout the PDES architecture. The purpose is to promote thoroughness in domain analysis and precision in definition and communication of information, especially between different layers. Examples of two types of application area reference models, produced using state of the art information modelling techniques, have been given above. These techniques feature a graphic form inasmuch as they are to support communication between humans, and also feature a computer-based language structure inasmuch as they are to support computer level operations. This feature allows the use of computer tools for use with reference models. For example, it would seem to be an absolute necessity that the reference model for the logical layer be able to be maintained using computer tools.

The first challenge here for a standards group that historically has been concerned with product data exchange issues is simply to learn something about reference models and information modelling, and about the requirements that any particular technique must satisfy in order to be useful. Another challenge is to effectively communicate the substance of these issues to people who are familiar with information modelling, but are probably not familiar with product data exchange, and to do this in a way that results in new talent being brought to bear on our problems.

Formal Languages

Formal languages will be used for the definition of data structures and for the PDES file syntax. Emphasis will be on languages with context-free grammars so that parsers can be built more simply.

Coordination With Other Standards

A final characteristic of the PDES methodology will be its relationship with other standards efforts, both national and international. How data is represented within PDES, as well as what data is represented will be coordinated with other efforts to insure compatability and to minimize duplication. For example, there already has been communication between PDES and X3H3 groups concerning minimization of duplication in connection with graphics presentation data. Another area open to potential coordination is the drafting area.

Some of the motivation for PDES having these characteristics can be traced to other data exchange efforts. The PDDI effort used the IDEF1 information modelling technique developed within ICAM. The PDDI methodology also emphasized the development of a conceptual schema described by a formal language, separation of physical data structure from the meaning of the data, and a physical file structure based on a formal language.

In addition to this, experience from the IGES efforts has shown that segmentation of the development of a standard along the lines of the three-level architecture would be a desirable thing. In the IGES efforts, there was no explicit segmentation. One result was that, in the course of pursuing new application areas, application-oriented people were being held responsible for things outside their area of expertise, such as the formulation of physical data structures. Another result was that there was no one explicitly charged with maintaining a global viewpoint toward the entity set and toward the consistency of the makeup of new entities. Thus, for example, relationships between application-specific and generic entities may not be consistent. In some cases the application specific entity may be primary, while in other cases the generic entity may be primary. Along the same lines, it was difficult to insure that the generic entity set was kept as lean and minimally redundant as possible.

PDES VERSION 1.0 - SCHEDULE AND ANTICIPATED CONTENTS

The target date for a draft PDES Version 1.0 document is December 31, 1986. While additions and/or deletions may yet occur, Version 1.0 contents as of this time are as follows:

Application Layer:

1. Geometry And Solid Modelling - Wireframe, Surfaces, B-Rep, CSG

2. Presentation - Viewing pipeline, View Mechanism, Text Definition

3. Mechanical - Several classes of parts modeled, including the classes of machined, turned, flat plate, and sheet metal

4. Electrical/Electronic - Schematics, Printed Wiring Board Physical Design

5. Manufacturing - Administrative data, Tolerance Model

6. AEC - HVAC Distribution Model

7. FEM - Functional capability of IGES Version 3.0 plus some postprocessing capability

Logical Layer - Develop conceptualization and integration methodology, and apply to application reference models

Physical Layer - Develop ASCII file format for a single PDES file

PDES PROOF OF CONCEPT WORK NOW UNDER WAY

A PDES proof-of-concept and general learning exercise has been under way since January of this year. This work is collectively known as the PDES Initiation effort, and is expected to be completed by April, 1986. The effort will involve all three layers of the architecture, but is being administered by two task groups. One is associated with the logical layer, and is chaired by J. C. Kelly of Sandia National Laboratories. The other is associated with the physical layer, and is chaired by W. B. Gruttke of McDonnell Douglas.

The goal of the Initiation work for the physical layer task group is the specification of a file structure for the PDES exchange form. The current (second) draft of the specification specifies the file structure as being language based, described by an unambiguous, context free grammar expressed in Bachus Nauer form. The specification draws heavily on previous PDDI experience in this area.

The Initiation work for the logical layer is divided into two tasks. The goals of the first task are to illustrate that a conceptual schema can be developed in support of a specific application area, and then to communicate this schema to the physical layer using a Data Specification Language (DSL). This initial conceptual schema will draw on reference models for flat plate mechanical parts, wireframe geometry, and graphic presentation that have been developed as part of this task. The master reference model for the conceptual schema will use the Nijssen Information Analysis Model (NIAM) information modelling technique, with the DSL description being generated manually from this. The DSL description of this conceptual schema is scheduled to go to the physical layer group on September 15. Present status is about two weeks behind this schedule.

The goals of the second task are to illustrate that the initial conceptual schema can be sequentially augmented in a consistent manner to support additional application areas, and then to communicate the augmented schema to the physical layer group. Four application area reference models have been developed for this task. They are in the areas of: Electrical, FEM, Tolerancing, and AEC/HVAC. All of these models use the IDEF1 information modelling technique with the exception of the AEC model, which uses NIAM.

(IDEF1 is an entity-attribute-relationship modelling technique, and NIAM is a binary relationship modelling technique. See the document entitled "Concepts And Terminology For The Conceptual Schema And The Information Base", published as SC21-N197 by ISO/TC97/SC21/WG5-3 for examples of the use of different modelling techniques to describe a conceptual schema.)

The master reference model for this task will also use the NIAM technique. The three IDEF1 models will be translated into NIAM models prior to the conceptualization and integration phase. Following this, the master reference model will be translated into DSL as in the first task. It is expected that communication of this DSL description to the physical layer group will occur approximately December 1.

The spirit of the initiation work is that we will do the best job possible within or nearly within the scheduled time, and then will examine and evaluate the products of our efforts and our methodologies, and for PDES longer term efforts will retain what is good and discard what is not.

Additional, more detailed information concerning the Logical Layer Initiation work is contained in the session handout.

THE PDES SPECIFICATION - SUMMARY

1. PDES is being developed to support industrial automation. It will deal with the entire range of product data and will represent the US position internationally in the quest for a single standard.

2. PDES content will emphasize solid modelling, complete product models, and product breakdown structure. It is intended that PDES will have a proactive influence on both users and vendors.

3. PDES Version 1.0 in draft form is targeted for December 31, 1986.

4. The PDES methodology is significantly different from the IGES methodology, and offers many challenges. It is based upon a three-layer architecture, reference models, conceptualization and integration, and formal languages.

5. Proof of concept work is currently under way and is known as the PDES Initiation effort. Content and methodology beneficial to long range PDES work will be kept.

6. Many fundamental PDES topics are yet to be widely discussed. Examples are requirements on pre and post processors for effective implementation of PDES, requirements on user databases to allow full advantage of PDES, and interplay between these.

CURRENT TASKS
OF PDES INITIATION EFFORT

(revised July 17, 1985)

	TASK	CHAIRMAN	AFFILIATION OF CHAIRMAN	ROLE
0.	GENERAL PDES CHAIRMAN	KALMAN BRAUNER (206) 251-2222	BOEING COMMERCIAL AIRPLANE COMPANY	INITIATE AND COORDINATE PDES ACTIVITIES
1.	REFERENCE MODEL METHODOLOGY	ROGER GALE (213) 318-2451	DAN APPLETON CO.	DETERMINE REFERENCE MODEL METHODOLOGY FOR PDES USE
2.	PHYSICAL FILE STRUCTURE/FORMAL LANGUAGE	BILL GRUTTKE (314) 234-5264	McDONNELL DOUGLAS AUTOMATION	FORMULATE PHYSICAL LAYER OF PDES UTILIZING FORMAL LANGUAGE TECHNIQUES
3.	CLASSIFICATION OF PRODUCT DATA	JERRY WEISS (314) 234-5155	McDONNELL AIRCRAFT	CLASSIFY CONTENTS OF LOGICAL LAYER FOR USE IN ORGANIZING THE STANDARD DEVELOPMENT EFFORT
4.	CONTENTS OF PDES START-UP EFFORT	J. C. KELLY (505) 844-1835	SANDIA NATIONAL LABORATORIES	DETERMINE CONTENTS OF PDES CORE

CURRENT PDES TASKS (Continued)

	TASK	CHAIRMAN	AFFILIATION OF CHAIRMAN	ROLE
5.	CHARTERS AND PROCEDURES	CURT PARKS (714) 620-7511 ext. 4300	GENERAL DYNAMICS	OVERSEE THE DEVELOPMENT OF ORGANIZATIONAL CHARTERS AND PROCEDURES GOVERNING PDES ACTIVITIES
6.	LIAISONS WITH OTHER STANDARDS	BERT GIBBONS (412) 778-5435	WESTINGHOUSE	INITIATE AND MAINTAIN DIALOG WITH OTHER STANDARDS BODIES RELATIVE TO PDES DEVELOPMENT
7.	LIAISON WITH VENDORS	RALPH MAYER (617) 937-3700	ADRA SYSTEMS	INITIATE AND MAINTAIN DIALOG WITH VENDORS RELATIVE TO PDES DEVELOPMENT
8.	REFERENCE MODELS FOR PDES START-UP EFFORT	J. C. KELLY (505) 844-1835	SANDIA NATIONAL LABORATORIES	DETERMINE REFERENCE MODELS FOR PDES CORE

CURRENT PDES TASKS (Continued)

TASK	CHAIRMAN	AFFILIATION OF CHAIRMAN	ROLE
9. LOGICAL ENTITIES FOR PDES START-UP EFFORT	J. C. KELLY (505) 844-1835	SANDIA NATIONAL LABORATORIES	DETERMINE LOGICAL LAYER FOR PDES CORE
10. APPLICATION LAYER COORDINATION	BILL MARKS (213) 616-3944	HUGHES AIRCRAFT	INITIATE AND COORDINATE APPLICATION LAYER ACTIVITIES
11. SOFTWARE DEVELOPMENT AND TESTING FOR THE PDES START-UP EFFORT	SPENCER DEPAUW (309) 578-3620	CATERPILLAR TRACTOR	PRODUCE PROTOTYPICAL SOFTWARE TO TEST THE VALIDITY OF THE CONCEPTS INCORPORATED IN THE PDES START-UP EFFORT
12. IGES TO PDES CONVERSION ALGORITHMS	RAYMOND BARKER (309) 578-6950	CATERPILLAR TRACTOR	DEVELOP ALGORITHMS TO CONVERT FILES IN IGES FORMAT TO PDES FORMAT
13. PDES NEWSLETTER	ROBERT COLSHER (312) 449-2118	IGES DATA ANALYSIS	PRODUCE THE PDES NEWSLETTER

CURRENT PDES TASKS (Continued)

TASK	CHAIRMAN	AFFILIATION OF CHAIRMAN	ROLE
14. IMPLEMENTATION AND VALIDATION	DAVID BRIGGS (ACTING) (206) 251-2222	BOEING COMMERCIAL AIRPLANE COMPANY	INITIATE AND COORDINATE IMPLEMENTATION AND VALIDATION ACTIVITIES

THE PRODUCT DATA EXCHANGE STANDARD (PDES)

Presented to:
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Standards for A Paperless World

September 9, 1985

J. C. Kelly
Sandia National Laboratories
Chairman, PDES Logical Layer Initiation Task

TOPIC AREAS

PDES SCOPE AND OBJECTIVES

THE PDES RELATIONSHIP TO IGES;
ITS DATA EXCHANGE HERITAGE

THE CONTENT EMPHASIS OF PDES

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CURRENT PDES PROOF OF CONCEPT WORK

SUMMARY

SOME EXAMPLES

PDE82

PDES SCOPE AND OBJECTIVES

PDES stands for Product Data Exchange Standard.
A long—term project within IGES exists to develop PDES.

The primary objectives are:

1. To develop an exchange standard for product data in support of industrial automation.
2. To represent the U.S. position in the International Standards Organization (ISO) arena for development of a worldwide standard.

No existing standard can be extended to adequately serve industrial automation.

PDES SCOPE AND OBJECTIVES, Cont'd

"Product Data" pertains to the entire product life cycle.

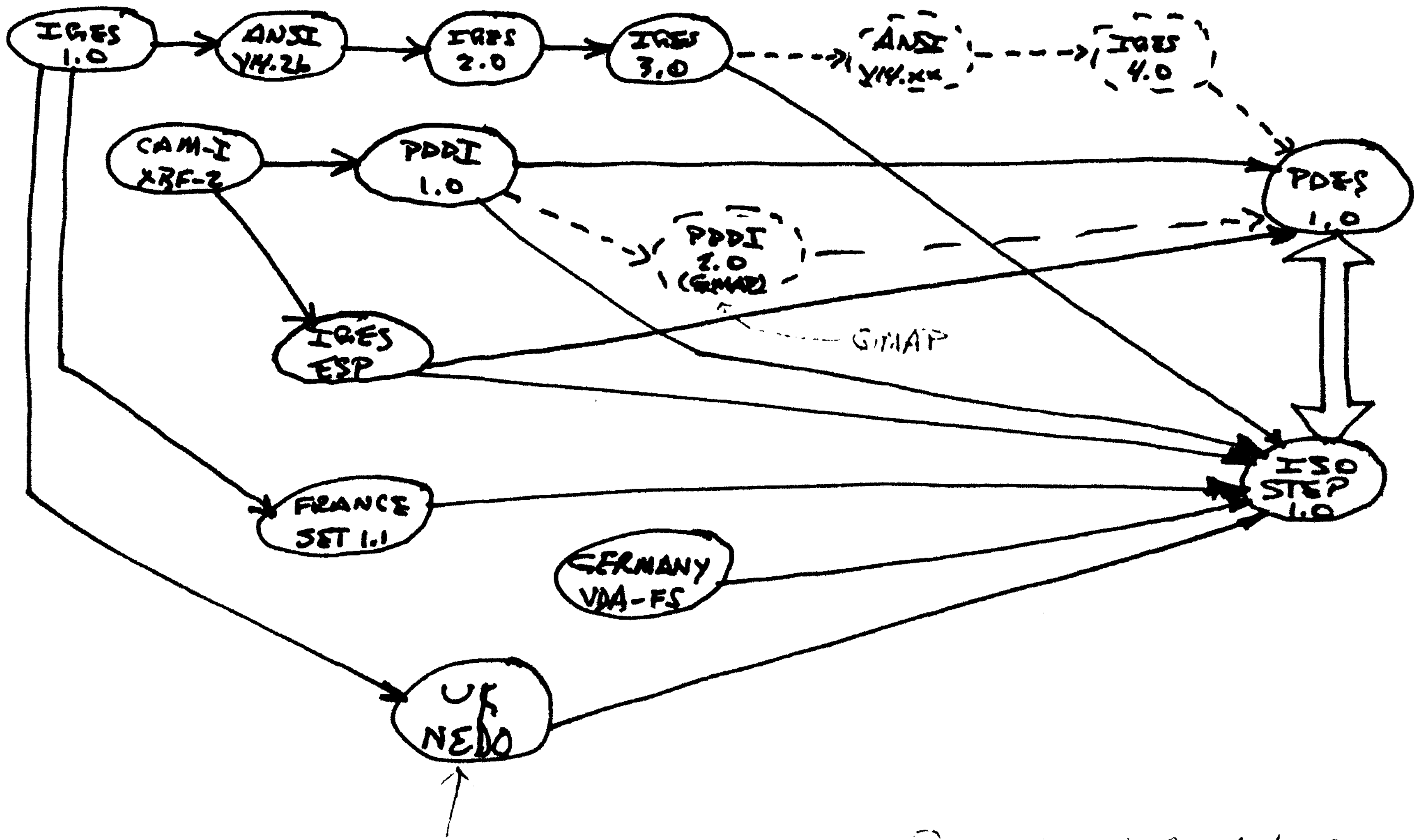
The ISO arena is TC184/SC4. There is agreement on the need for a single worldwide standard. To be called STEP.

Version 1.0 Technical Specification by December 31, 1986. Effective industrial use by 1990.

The U. S. intention is that PDES and STEP be identical.

pdes4

LONG TERM DATA EXCHANGE SPECIFICATION DEVELOPMENT



~~One viewfoil with PDDI 2.0 and one without.~~

~~Need by Sept. 4~~

THE PDES RELATIONSHIP TO IGES; ITS DATA EXCHANGE HERITAGE

IGES VERSION 3.0 IS IN FINAL EDITORIAL REVIEW. UPWARD COMPATIBLE VERSIONS OF 3.0 WILL CONTINUE TO BE DEVELOPED.

A DRAFT VERSION OF PDES VERSION 1.0 IS TARGETED FOR DECEMBER 1986. MINIMALLY, THIS IS TO BE FUNCTIONALLY EQUIVALENT TO THE THEN—CURRENT IGES VERSION, PERHAPS 4.0.

FROM THAT POINT, DEVELOPMENT EMPHASIS IS TO BE TOWARD PDES. MAINTENANCE EMPHASIS IS TO IGES.

THE PDES RELATIONSHIP TO IGES Cont'd

THE PDES HERITAGE FROM THE IGES VERSIONS IS:

DATA EXCHANGE BETWEEN INTERACTIVE GRAPHICS CAD/CAM SYSTEMS IS THE DRIVING FORCE.

EARLY VERSIONS IMPLICITLY EMPHASIZED MECHANICAL APPLICATION AREA. FOCUS WAS 2D DRAWINGS, 3D WIREFRAME, SOME SURFACES. LATER VERSIONS EXPANDED TO OTHER APPLICATON AREAS.

THE PREVAILING SPIRIT IS THAT THE MEANING OF THE DATA IS TO BE IMPOSED FROM OUTSIDE THE DATA — SAY, BY A HUMAN AT A GRAPHICS TERMINAL. NOT AUTOMATION — ENABLING.

PDES RELATIONSHIPS; PDES HERITAGE, Cont'd.

The PDES Heritage From Some Other Efforts Includes:

An emphasis on solid modelling:

CAM—I XBF—2 — B—Rep, CSG, Topology
IGES ESP — B—Rep, CSG, Topology

PDDI — B—Rep, Topology, Features
GMAP — Emphasis On Data Exchange Across The Range Of The Geometric Modelling Taxonomy.

PDES RELATIONSHIPS; PDES HERITAGE, Cont'd.

The PDES Heritage From Other Efforts Also Includes:

An emphasis on a "complete" product model.

PDDI — Satisfy needs of manufacturing from design.
GMAP — Extend to include analysis, inspection, and product support.

A complete product model includes both shape and non—shape information, associated as required. The information is in an automation—enabling form.

THE CONTENT EMPHASIS OF PDES

The PDES effort will reflect this dual heritage and will extend it. Intends to have a proactive influence on both users and vendors.

PDES will accommodate drawing representation, wireframe geometry, surfaces, as did efforts in the first group.

But the PDES effort will have advanced geometry modelling and complete product models as its driving forces, as did efforts in the second group.

THE CONTENT EMPHASIS OF PDES, Cont'd.

PDES will extend its heritage by providing a means to communicate a product breakdown structure.

This implies accommodation of such notions as: Part, Subassembly, Assembly, Version, Effectivity, etc.

This also implies accommodating the natural correspondence between these notions and the configuration documents, test data, change directives, etc., that pertain to them.

THE CONTENT EMPHASIS OF PDES, Cont'd.

To communicate a product breakdown structure, it will be necessary to:

Find a way to relate product breakdown structure to the PDES file or files representing the product.

Find a way to incorporate enough flexibility to accommodate diverse companies having diverse needs.

THE PDES METHODOLOGY AND ITS CHALLENGES

The PDES methodology is significantly different from the IGES methodology.

It involves:

A three—layer architecture similar to the three—schema framework for DBMS as outlined by ANSI/X3/SPARC.

Reference models using computer—based information modelling techniques and associated tools.

Formal languages.

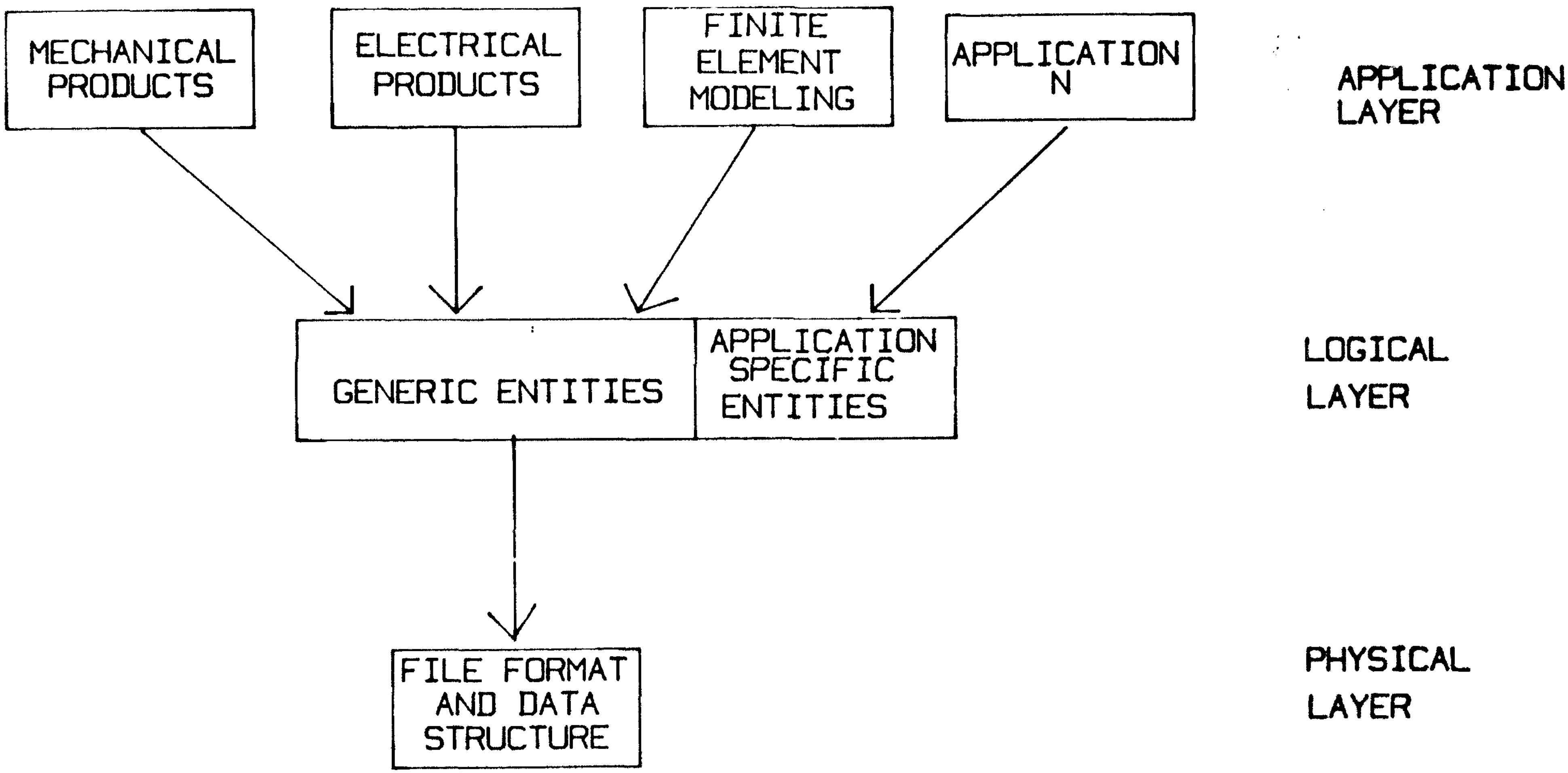
Coordination with other standard's efforts.

THE ANSI/X3/SPARC DATABASE ARCHITECTURE

$$\begin{array}{c}\text{EXTERNAL LEVEL}\\ \updownarrow \\ \text{CONCEPTUAL LEVEL}\\ \updownarrow \\ \text{INTERNAL LEVEL}\end{array}$$

EXTERNAL LEVEL	Supports user views of the enterprise. Serves application programmers and query language users. Multiple schemas possible.
CONCEPTUAL LEVEL	Supports the enterprise and its single world view. A single conceptual schema.
INTERNAL LEVEL	Supports the DBMS and the machine itself. A single internal schema.

THREE LAYER PDES ARCHITECTURE



THE PDES METHODOLOGY, Cont'd.

The three layers in the architecture are: The application layer, the logical layer, and the physical layer.

Logical Layer: Corresponds to the conceptual schema. The central, computer–independent description of the data constructs that will contain the information to be exchanged. The challenge is the conceptualization and integration across diverse application areas. To originate and consistently expand the set of data constructs.

THE PDES METHODOLOGY, Cont'd

External Layer: Corresponds to the external schema. User views of the constructs required to support a particular application area. The challenge is to do the modelling of the application areas, and then to manage the networking of these to support complete product models.

Physical Layer: Corresponds to the internal schema. Concerned with the data format for the exchange file itself. The challenge will be to establish and maintain efficiency in file size and processing time.

THE PDES METHODOLOGY, Cont'd.

Reference models using computer based information modelling techniques will be used to promote thoroughness, consistency, precision in communication, and to allow computer based tools to be used, say, for maintainability.

A formal language will be used to describe the physical file structure. Some information modelling is language—based.

Coordination with other standards is to minimize duplication.

PDES VERSION 1.0

SCHEDULE AND POSSIBLE CONTENT AREAS

The target date for a draft of PDES Version 1.0 is December 31, 1986.

Possible content areas include:

- Wireframe and Surface Geometry
- Solic Modeling — B—Rep, CSG
- Presentation — Views, Text
- Mechanical — Part Classes Modeled
- Electrical — Schematics, Printed Wiring Board Physical Design
- Manufacturing — Adminstrative Data, Tolerances
- AEC — HVAC Distribution Model
- FEM — Nodes, Elements, Loads/Constraints, Displacements, Postprocessing

Conceptualization and Integration Methodology Applied to Models

Language—based ASCII File Format

PDES PROOF OF CONCEPT WORK UNDERWAY

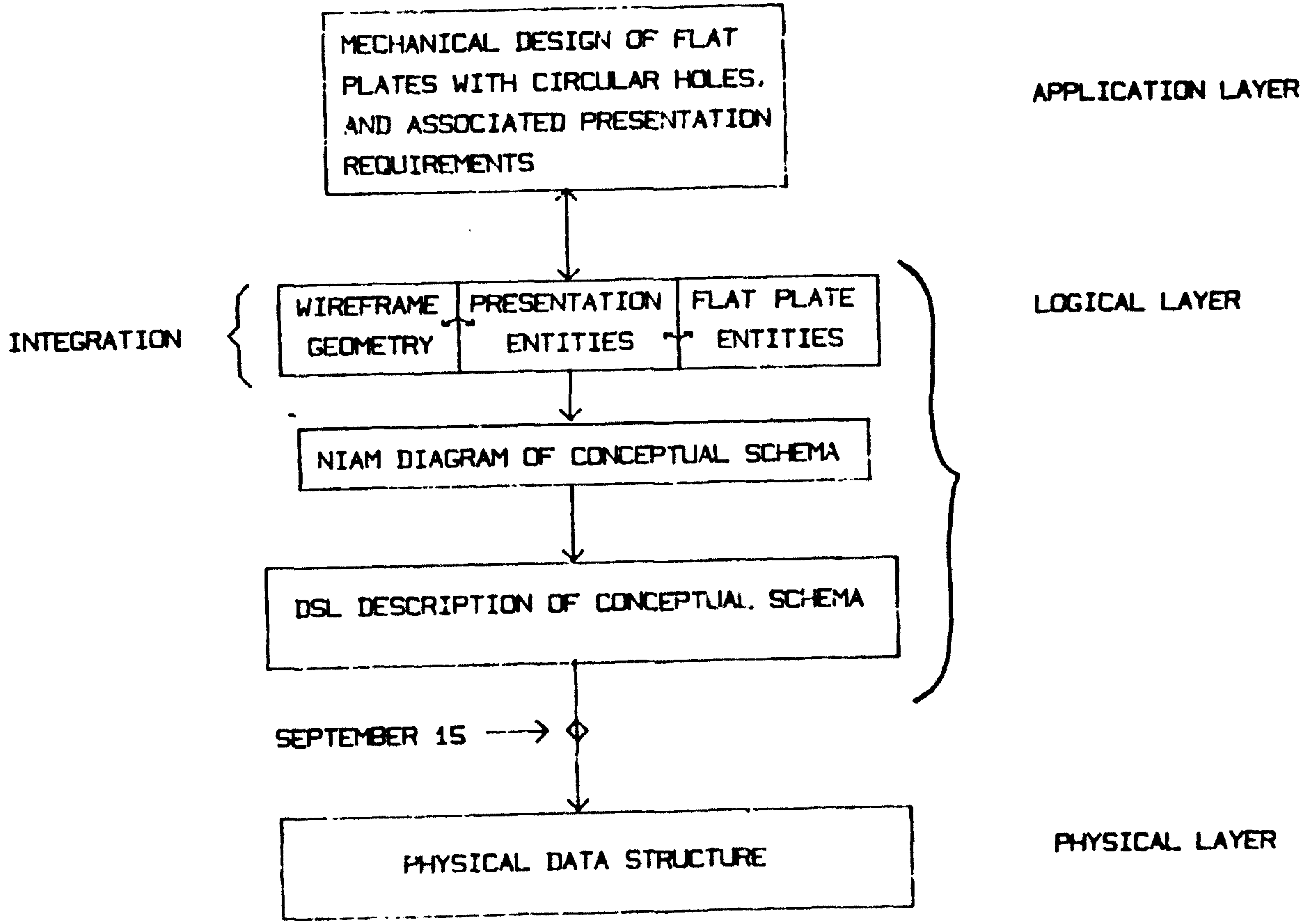
Logical Layer Initiation Work:

1. Develop a Conceptual Schema for an Application and Communicate it to the Physical Layer.
2. Sequentially augment the Conceptual Schema to support additional Application Areas.

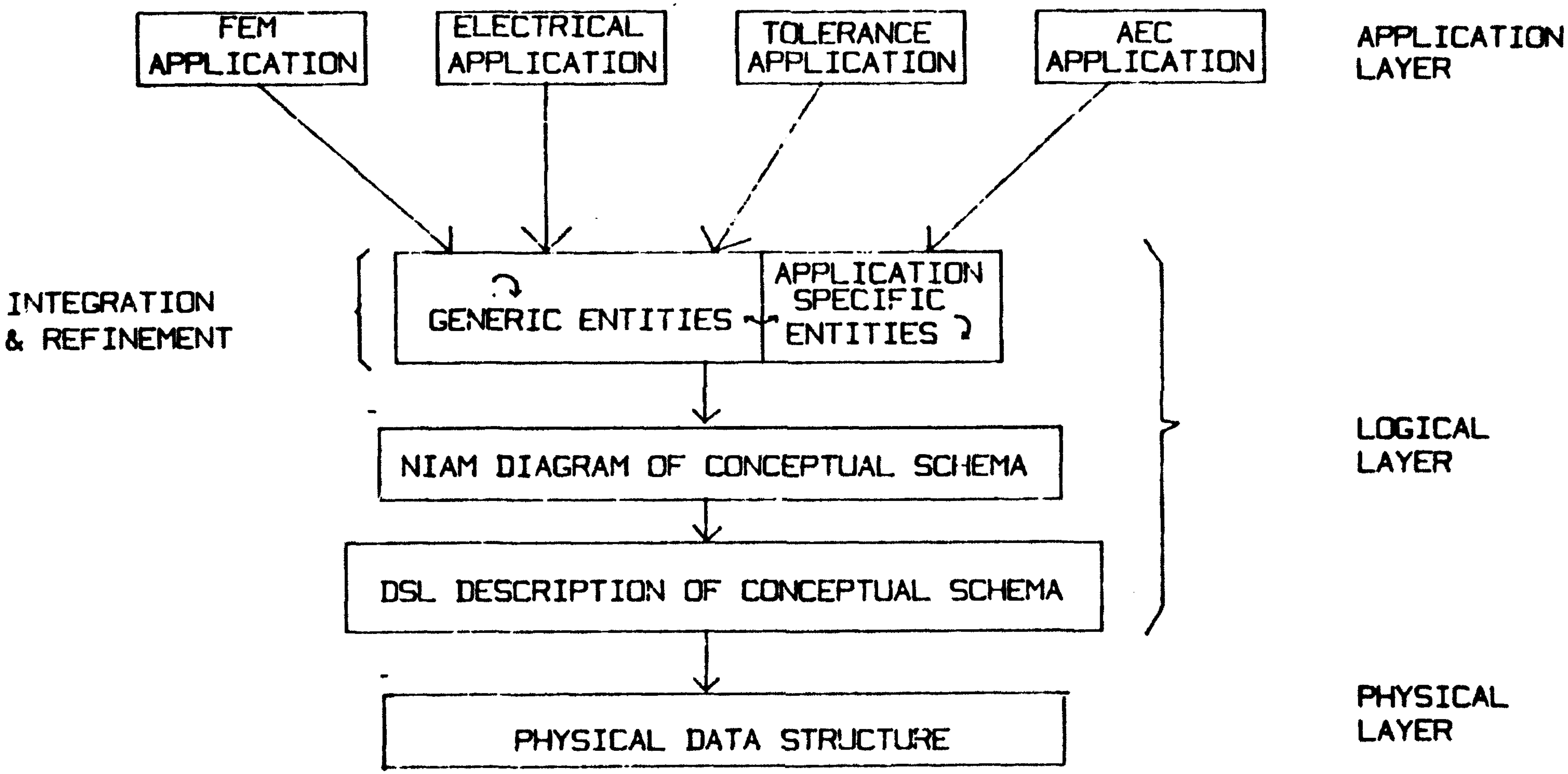
Physical Layer Initiation Work:

Language—Based ASCII File Format

OVERVIEW OF TASK 1



OVERVIEW OF TASK 2



PDES PROOF OF CONCEPT WORK, Cont'd

The Spirit of the Initiation Work is:

Best Job Possible on or near Schedule

Examine and Evaluate Methodologies, Content

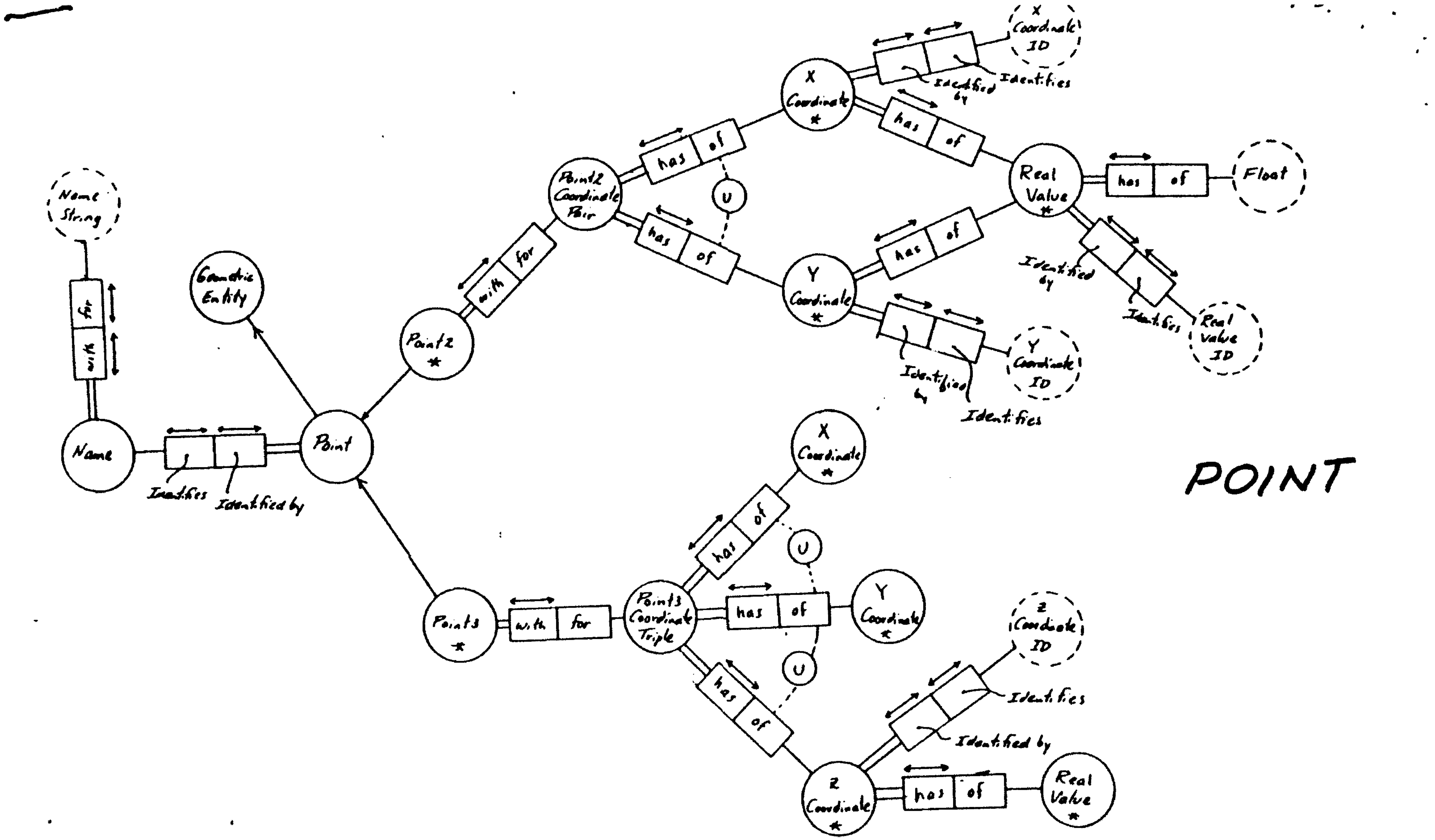
Keep What Is Good for Longer Term PDES

Discard What Is Not

THE PDES SPECIFICATION

SUMMARY

1. PDES will support industrial automation. It will represent the U.S. position internationally.
2. PDES content will emphasize solid modelling, complete product models, and product breakdown structure.
3. PDES Version 1.0 draft is targeted for December 31, 1986.
4. PDES methodology is significantly different from the IGES methodology.
5. PDES initiation work is proof of concept work and is currently underway.
6. Many fundamental PDES topics are yet to be widely discussed.


POINT
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Identifies
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Point
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for
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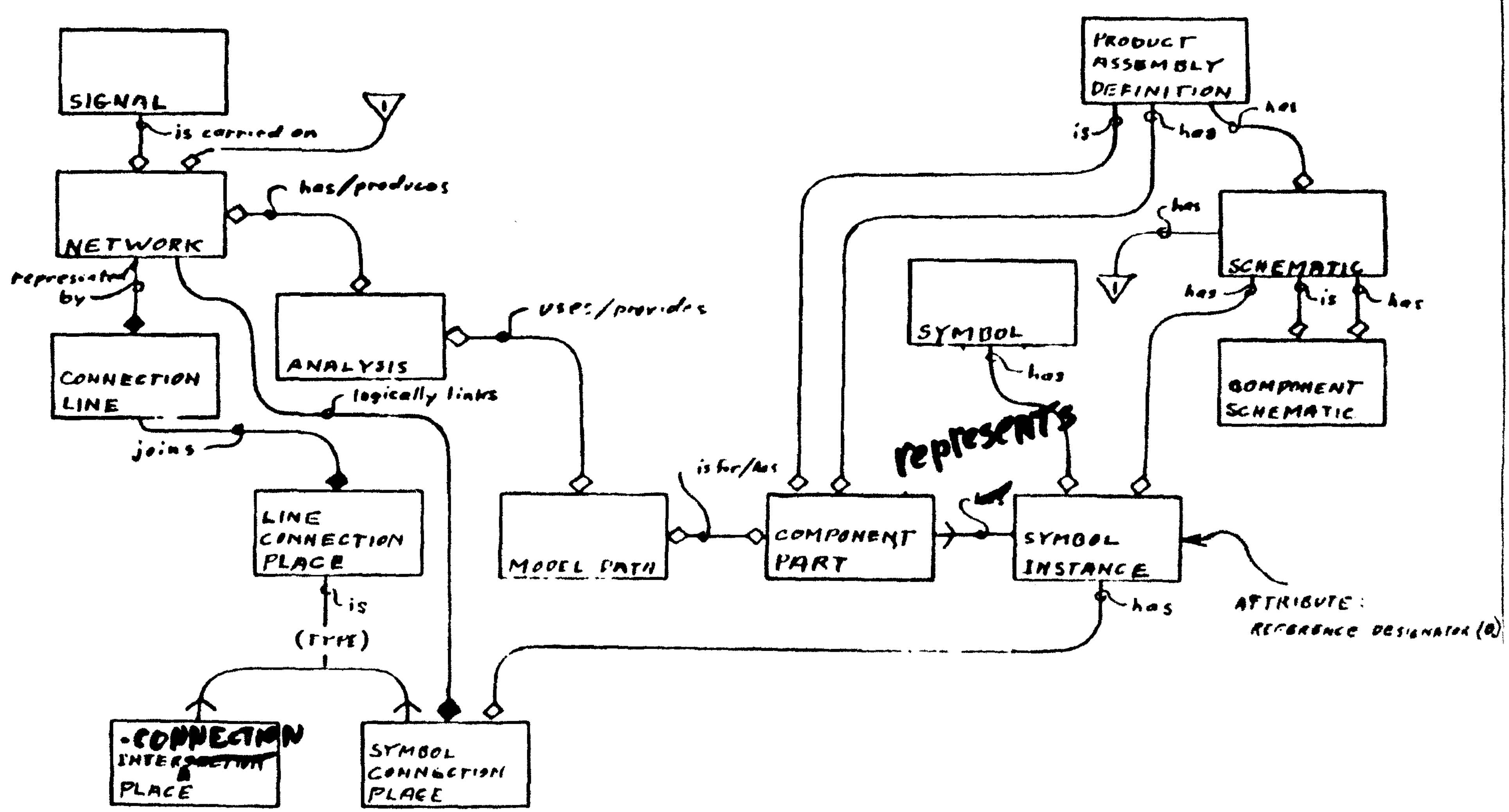
X Coordinate ID
Y Coordinate ID
Identified by
Identifies
Real Value *
Float
Real Value ID
Point3 *
Point3 Coordinate Triple
Z Coordinate *
Z Coordinate ID
Real Value *

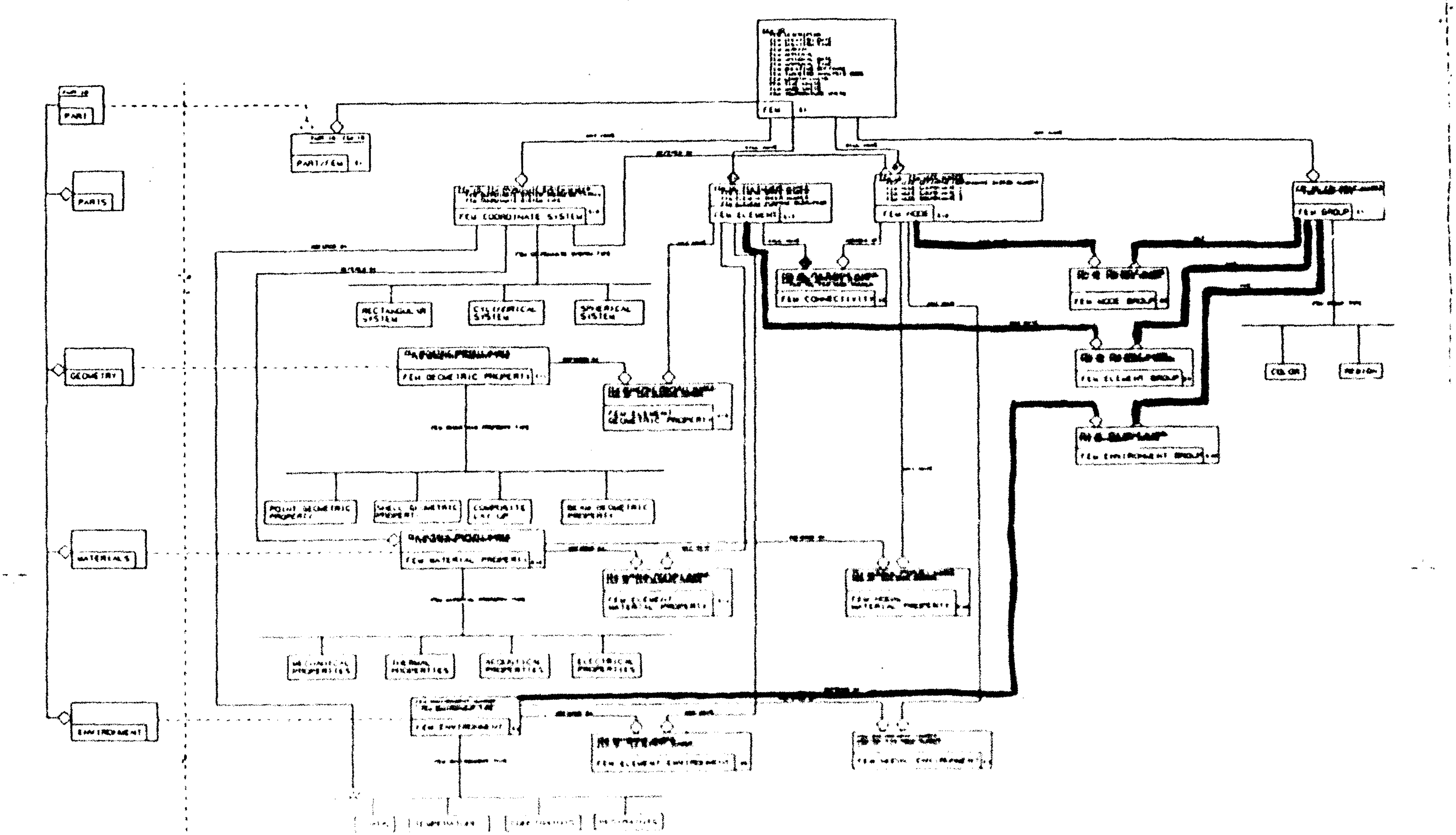
IDEF

USED AT:	AUTHOR: NELSON, PARKS PROJECT: IGES SCHEMATIC LOGICAL SCHEMA NOTES: 1 2 3 4 5 6 7 8 9 10	DATE: JAN. 1985 REV: MAR. 1985		WORKING	READER	DATE	CONTEXT:
			X	DRAFT			
				RECOMMENDED			
				PUBLICATION			



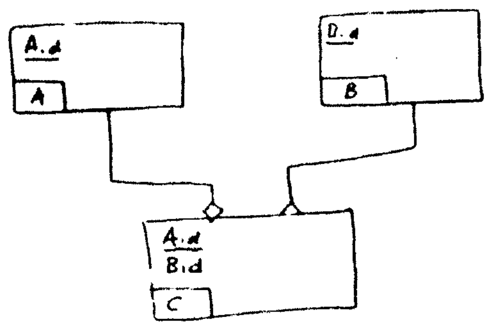
NODE: FE-1	TITLE: SCHEMATIC OVERVIEW FEO (For Exposition Only)	NUMBER: A/ESCH/C-10-7

IDEF1 MODEL OF FINITE ELEMENT MODEL (FEM)

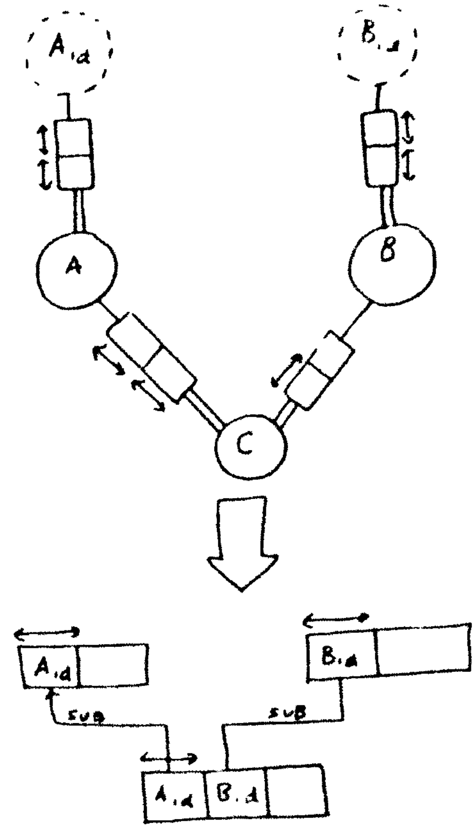


Association 2

IDEF1



NIAM



Session Handout

Federal Computer Conference

September 9,10,11, 1985

Washington Convention Center

Theme Track: Tying It All Together
Session: Product Data Exchange
Topic: Product Data Exchange Standard (PDES)

Speaker: J. C. Kelly, Sandia National Laboratories

Charter

Of The

PDES Logical Layer Initiation Task Group

Submitted By:

J. C. Kelly
Sandia National Laboratories
Chairman, Logical Layer Initiation
Task Group

July 30, 1985

Note: The following material constitutes operational papers describing work in progress or work projected to be done as part of the PDES Initiation Effort, and does not comprise any official policy on behalf of any IGES or PDES Committee, especially with regard to the contents of future versions of PDES and the methodology by which those versions might be produced. Actual work performed as part of the Logical Layer portion of the Initiation Effort may vary depending on schedules and/or the amount of volunteer manpower that participating companies are able to devote to the tasks described.

Charter Of The PDES Logical Layer Initiation Task Group

The PDES Logical Layer Initiation Task Group is an ad hoc subcommittee of the PDES Committee. This Task Group will perform work as described below as part of the PDES Initiation effort.

The purposes of the work of this Task Group are:

1. Examine the possibility and feasibility of developing PDES according to the three level ANSI/X3/SPARC architecture as suggested in the second PDES report.

2. Establish logical layer content which potentially could serve as a baseline for future PDES development.

The two main tasks of this Task Group are:

1. Illustrate that a conceptual schema can be developed in support of a specific application area, and communicate the structure of this schema to the PDES Physical File Structures and Formal Languages Task Group.

2. Illustrate that this conceptual schema can be augmented in a non-redundant manner on an application-by-application basis.

The first task will contribute to illustrating the use of all three levels of tne three level architecture. The second task will illustrate that the conceptual schema can be incrementally augmented as the need arises - a characteristic of the PDES environment.

Each task will result in a communication of the conceptual schema content to the Physical File Task Group. A Data Specification Language will be used for this. Communication for the first task will be approximately mid-September, 1985, and communication for the second task will be approximately November 1, 1985.

Requests will be made of application groups to compose reference models to be used in the second task. These groups could conceivably be based in existing IGES Subcommittees, or could be ad hoc.

A final report will be written. The report will describe and document what work was performed, and will make recommendations based on this experience. The general time frame for this report is January 1, 1986.

The Task Group will meet as required in order to accomplish its work, and will periodically report on its progress.

Task Overview

Task 1 A conceptual schema will be developed to support the mechanical design of flat plates with circular holes. Wireframe geometry will be used. The schema will support some user-view presentation (viewing) scenarios pertinent to this area of mechanical design.

The wireframe geometry entities and the presentation entities will be developed as part of this task. A reference model describing the conceptual schema will be produced. The Information Analysis (IA) information modeling methodology will be used for this reference model, and the Data Specification Language (DSL) description of the conceptual schema will be based on this reference model.

Task 2 Four Application Task Groups will be contacted to compose reference models. These models will be used one at a time to cumulatively augment the conceptual schema produced in the first task. A reference model depicting the "final" conceptual schema will be produced, as will a mapping illustrating how each application makes use of the conceptual schema. The cumulative augmentation of the conceptual schema will involve integration in the sense that a minimum number of "generic" entities and structures will be sought to support the common needs of the various applications.

The integration work is the focal point of this task. The Information Analysis (IA) modeling methodology, and associated Software Tools (ST), will be used to support this work. (Specifically, IAST, a CDC software product in the possession of those who will be doing the integration work, will be used.) In order to provide a common footing for the integration work, and to make possible the use of the supporting software, each reference model from an Application Task Group will be translated into an equivalent IA-based reference model, and entered into IAST. The resulting translated reference model will be scrutinized from a "Quality Assurance" point of view. A liason from the referring Application Task Group will assist in understanding and possibly refining the reference model, thereby closing the QA loop.

IA will be used to describe the final conceptual schema, and also to illustrate how each application makes use of the conceptual schema. As in the first task, the Data Specification Language description of the conceptual schema will be based on the IA reference model of the conceptual schema.

The Application Reference Models Are:

1. Mechanical Design - Flat Plates With Circular Holes
2. Electrical Design - Schematics
3. Tolerancing - Tolerances In Y14.5M And ISO 1101 and 1660
4. Finite Element - Finite Element Environment
5. AEC - AEC/HVAC

Recommendations For General PDES Evaluations, recommendations, and experiences based on this work will include:

1. An evaluation of the three level architecture as an environment for developing PDES.
2. Recommendations for a logical layer integration methodology.
3. Recommendations for application layer information modeling techniques.
4. Experiences with the use of automated tools.

PDES Logical Layer Initiation Task Group

I. Bodnar, CDC
D. Briggs, Boeing
R. Brown, Hughes (New Member)
E. Clapp, IBM, Wireframe Geometry Task Leader
S. DePauw, Caterpillar, Flat Plate Design Task Leader
R. Gale, DACOM
D. Hemmelgarn, ITI
J. C. Kelly, Sandia, Chairman
P. Kennicott, GE
H. Ladd, DuPont (New Member)
D. Schenck, McDonnell-Douglas, DSL Task Leader
D. Theilen, Allied/Bendix, Logical Layer Integration Task Leader
D. Winfrey, DEC, Presentation Task Leader
J. Zimmerman, Allied/Bendix

Application Layer Tasks Initiated By Request Of The Logical Layer Initiation Task Group And Their Coordinators With The Logical Layer

1. Mechanical Design - Reference Model For Flat Plates
   S. dePauw - Caterpillar, Task Leader
   D. Hemmelgarn - ITI

2. Electrical Design - Reference Model For Schematics
   C. Parks - General Dynamics, Task Leader
   P. Kennicott - General Electric
   Work Supported By: IGES Electrical Subcommittee

3. Tolerancing - Reference Model For Tolerances In Y14.5M
   R. Colsher - IGES Data Analysis, Task Leader
   B. Burkett - McDonnell-Douglas
   Work Supported By: IGES Drafting Information Model WG

4. Finite Element - Reference Model For FE Environment
   R. Ivey - Westinghouse, Task Leader
   B. Freeman - Allied/Bendix
   Work Supported By: IGES FEM Subcommittee

5. AEC - Reference Model For AEC/HVAC
   F. Stahl, IBM, Task Leader
   P. Rourke, Newport News Shipbuilding
   J. Turner, University Of Michigan
   Work Supported By: IGES AEC Subcommittee

THE PDES LOGICAL LAYER INITIATION TASK

A SUBTASK OF THE PDES INITIATION ACTIVITIES

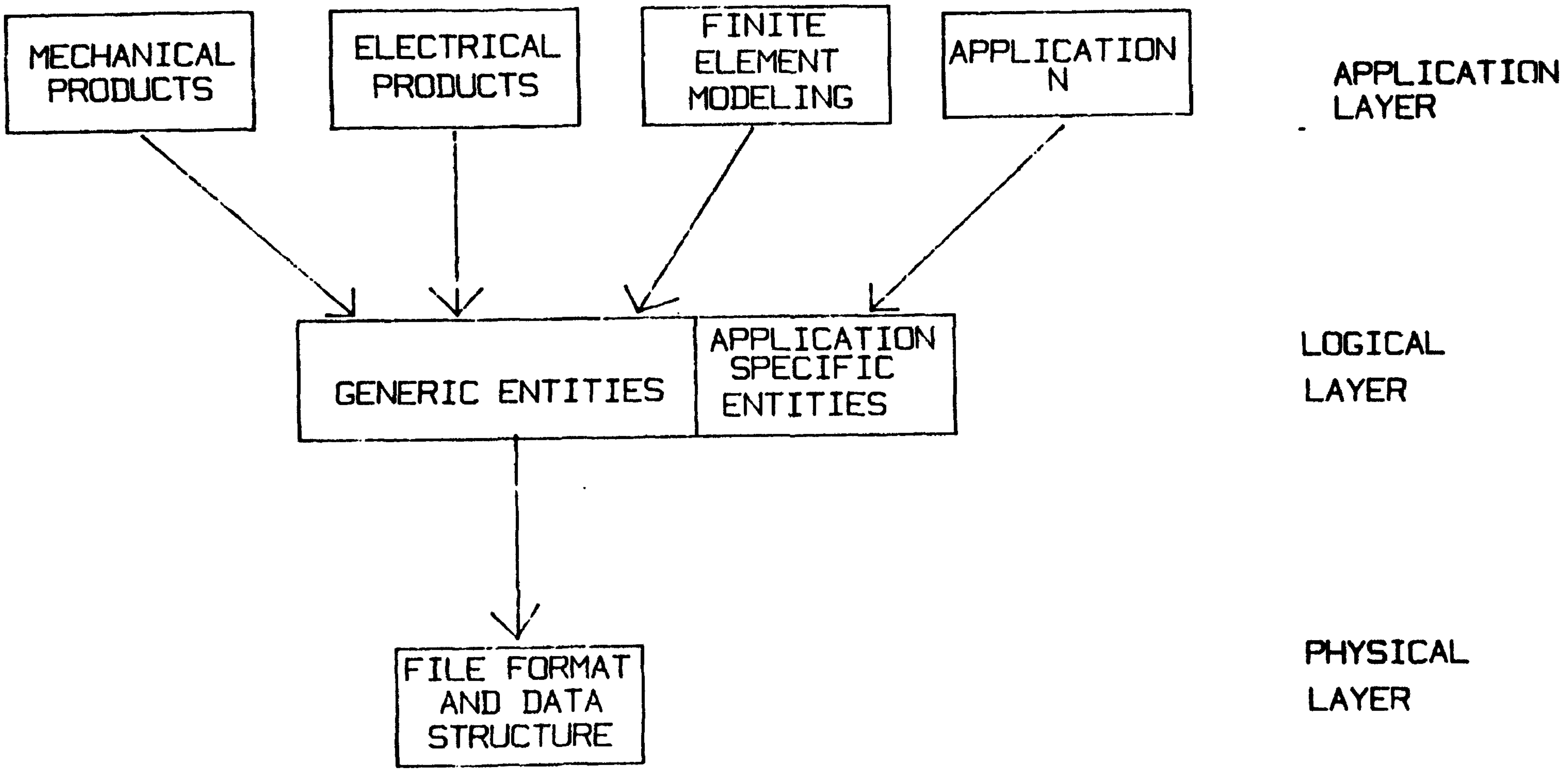
J. C. KELLY, Chairman
SANDIA NATIONAL LABORATORIES

THE ANSI/X3/SPARC DATABASE ARCHITECTURE

$$\begin{array}{c}\text{EXTERNAL LEVEL}\\ \updownarrow\\ \text{CONCEPTUAL LEVEL}\\ \updownarrow\\ \text{INTERNAL LEVEL}\end{array}$$

EXTERNAL LEVEL	Supports user views of the enterprise. Serves application programmers and query language users. Multiple schemas possible.
CONCEPTUAL LEVEL	Supports the enterprise and its single world view. A single conceptual schema.
INTERNAL LEVEL	Supports the DBMS and the machine itself. A single internal schema.

THREE LAYER PDES ARCHITECTURE



PURPOSES OF THE TASK GROUP WORK:

1. Examine the possibility and feasibility of developing PDES according to the three level ANSI/X3/SPARC architecture.

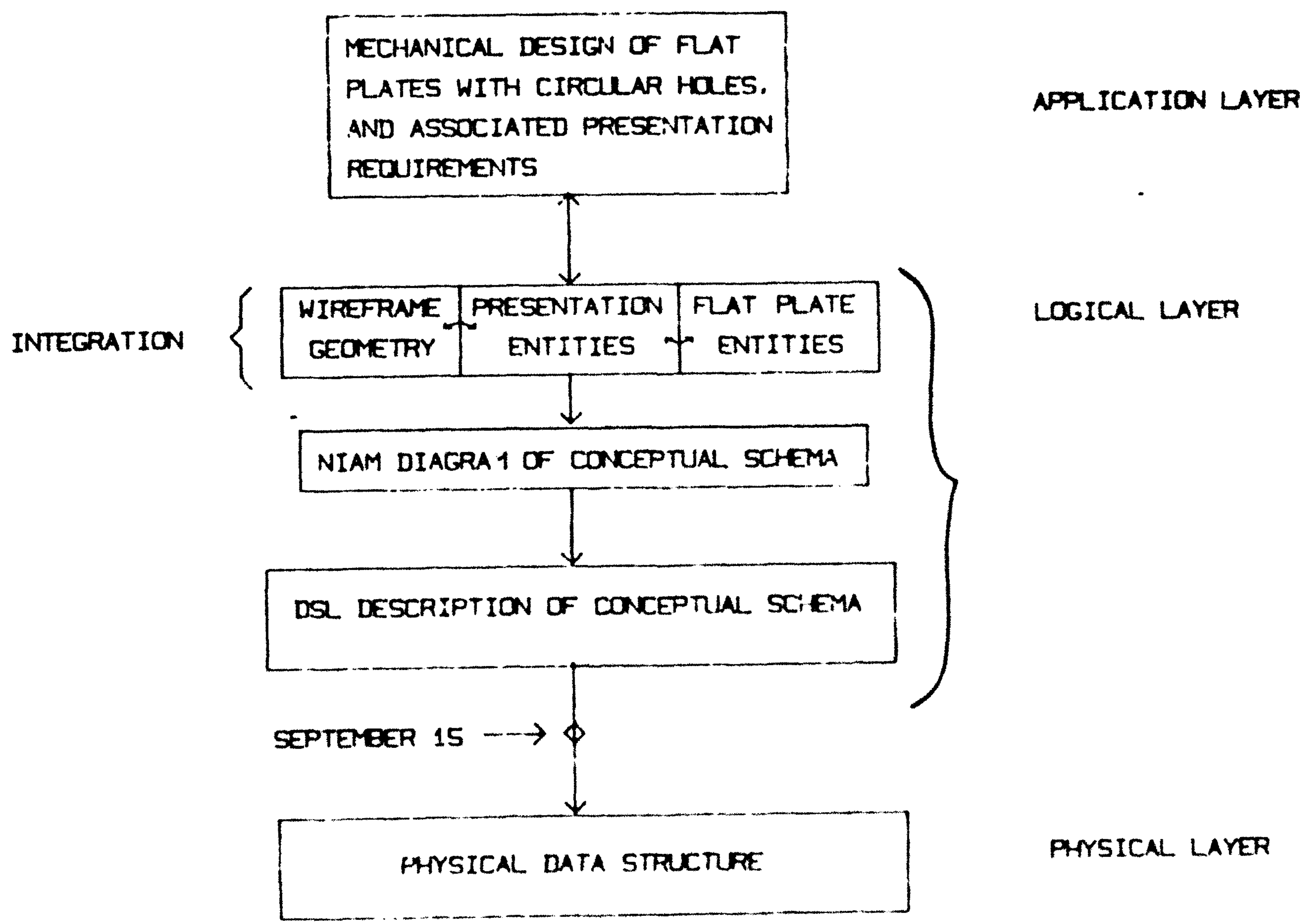
2. Establish logical layer content which potentially could serve as a baseline for future PDES development.

TWO MAIN TASKS:

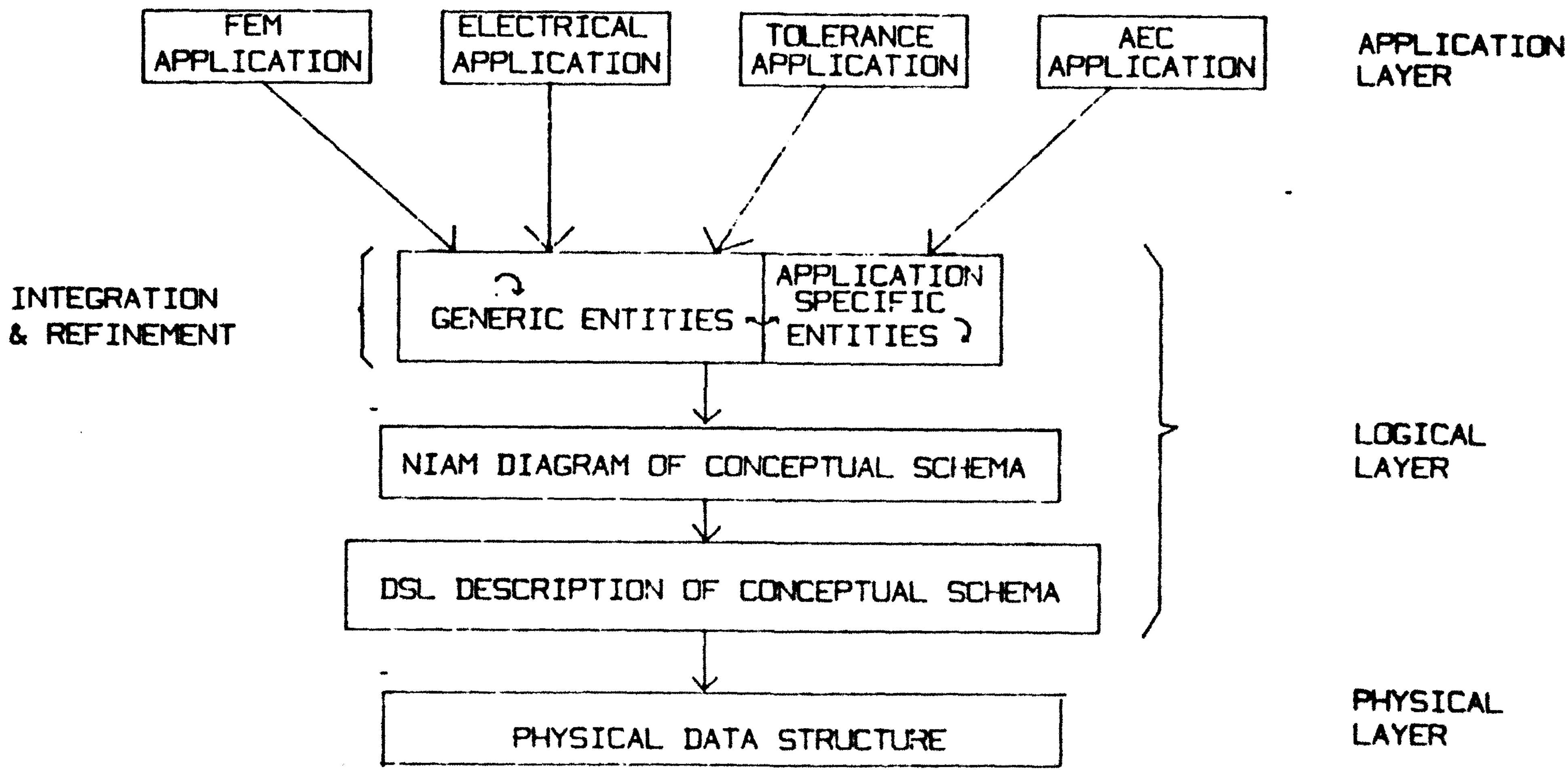
1. Illustrate that a conceptual schema can be developed in support of a specific application area, and communicate the structure of this schema to the PDES Physical File Structure and Formal Languages Task Group.
   HELPS ILLUSTRATES USE OF ALL THREE LAYERS

2. Illustrate that the conceptual schema can be augmented in a non-redundant manner on an application-by-application basis.
   CHARACTERISTIC OF THE PDES ENVIRONMENT

OVERVIEW OF TASK 1



OVERVIEW OF TASK 2



PDES Logical Layer Integration Subtask

Subtask Leader: Dave Theilen, Allied/Bendix Aerospace, Kansas City

A FINAL REPORT WILL DESCRIBE AND DOCUMENT THE WORK PERFORMED, AND WILL GIVE:

1. An evaluation of the three level architecture as an environment for developing PDES.
2. Recommendations for a logical layer integration methodology.
3. Recommendations for application layer information modeling techniques.
4. Experiences with the use of automated tools.

REPORT TARGETED FOR JANUARY 1, 1986.

finirept

PDES Initiation Logical Layer Methodology

Principal Author: John Zimmerman, Allied/Bendix Aerospace, Kansas City

The primary mission of the Logical Layer Initiation Effort is to develop the definition of the logical entities required to meet the needs of all applications within the initiation scope. This includes "generic entities" which are required by two or more applications and "application specific entities" which are used in only one application area. This set of entities and their relationships is referred to as the conceptual schema.

The Primary goal of the PDES Initiation Logical Layer Methodology is to guide the Logical Layer Initiation Effort in the development of the conceptual schema for Task 1 and Task 2 of the PDES Initiation Effort as described in the PDES Logical Layer Charter.

The following are key success factors for this methodology:

1. Maximize usage of state-of-the-art conceptual modelling techniques and tools.

2. Support the integration of the three PDES architectural layers (application, logical, and physical) as described in "The Second PDES Report".

3. Maximize the usage of human resources in development of the conceptual schema by defining and establishing project roles.

4. Simplify the methodology as much as possible.

5. Give the methodology growth potential so that it can support future PDES efforts.

6. Maximize the potential of the conceptual schema to serve as a central resource from which all other PDES forms can be computed.

Methodology Overview

Refer to the accompanying figure for a graphical overview of the methodology. The numbering of the models is consistent with the US Position paper "Reference Models, Development Methodology, and Entity Subsets for STEP" submitted to ISO/TC184/SC4/WG1 by the US TAG.

The methodology is broken into three phases:

PHASE 1: Pre-conceptualization. In this phase all application area reference models, regardless of modelling form, are reduced to binary form to maximize potential for conceptualization and integration. When these binary models are verified against the original application area model they are considered "qualified".

PHASE 2: Conceptualization and Integration. In this phase conceptual entities and relationships are discovered. An integrated conceptual model is built from which can be derived (via mappings) any application area reference model. A conceptual architecture will be built that models all conceptual categories. This architecture will be stored in a dictionary which will be developed in this stage. It is in this phase that the maximum potential of the conceptual schema will be realized.

PHASE 3: Post-Conceptualization. In this phase the binary conceptual schema will be conditioned in preparation for development of the physical file format. The conceptual schema is grouped into a nested record form called Data Specification Language (DSL). This DSL form is the ultimate deliverable to the physical file layer. The ultimate source of the DSL will always be the binary conceptual schema.

Methodology Details

PHASE 1: Pre-conceptualization

Goal: To maximize the conceptualization and integration potential of the application area models.

Input: Application area reference models.

Deliverable: A computerized binary model verified to be equivalent to the original application area reference model.

Description: This phase of the methodology conditions the application area reference model in preparation for conceptualization and integration. In the PDES Initiation Effort application area reference models may be of any form that has a reasonable degree of rigor. The conditioning process converts these diverse forms into a single standard semantic form. The standard semantic form is the binary model. Specifically, Nijssen's Information Analysis Model (NIAM) will be used.

All application area reference models are manually reduced to binary form and entered into an electronic data base (CDC's Information Analysis Support Tool - IAST). This model database is echoed back to the application area in the form of natural language sentences derived manually from the binary model and in computer-generated relational structures. The relational structures are used for the validation of binary models that have been translated from record-oriented application area models. The natural language sentences are returned to the application area for approval. The binary model is considered to be "qualified" when the natural language sentences are approved and the relational structures are verified to be equivalent to the original record-oriented model. It is presumed that most application area reference models will be record or relationally oriented.

Even though the computer generated relational model may be useful in follow-on PDES efforts, its only use in the Initiation Effort is the validation of record-oriented reference models. The deliverable of this phase is the binary conceptual model.

Initiation
Archictecture & Development Methodology

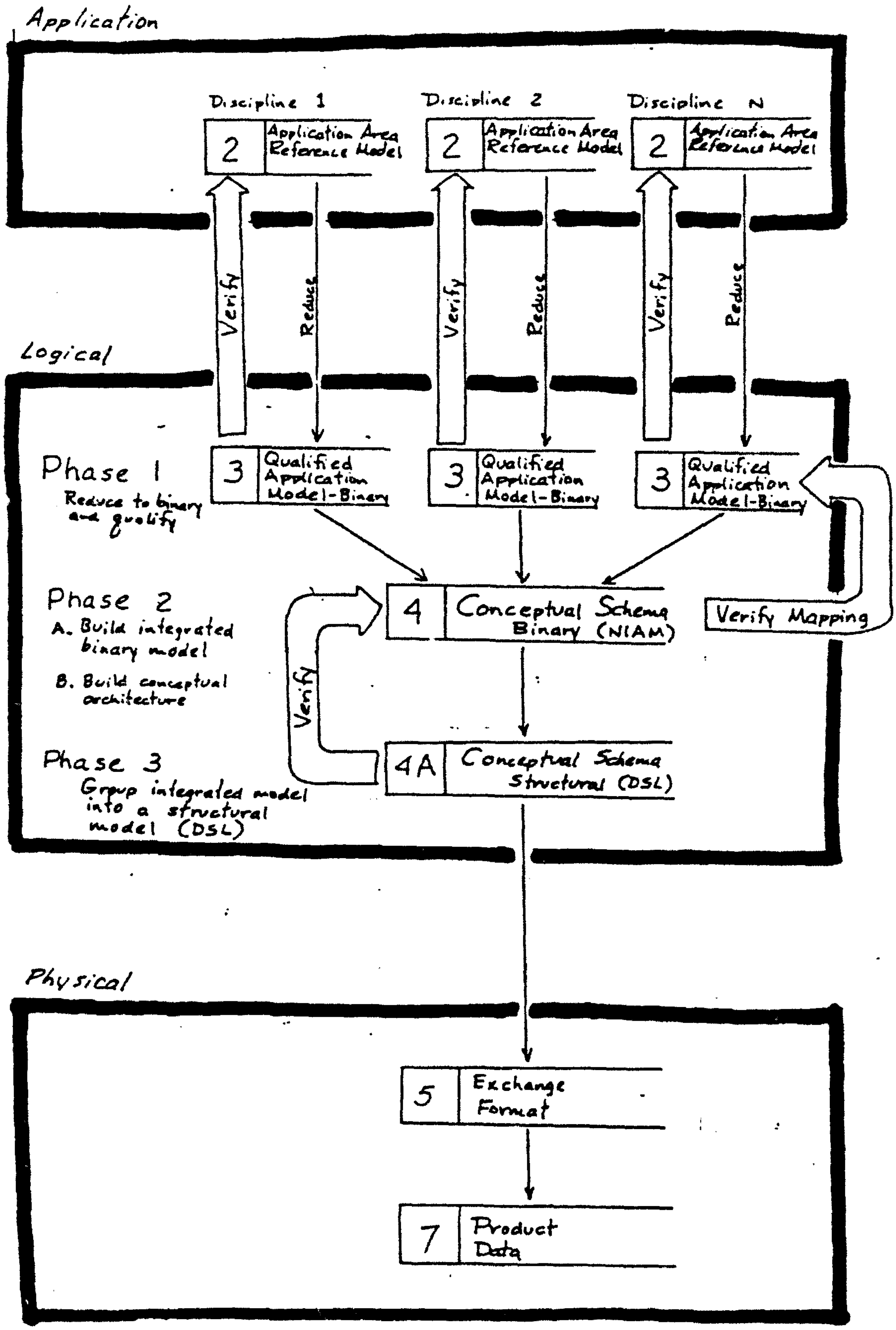


FIGURE 1

PHASE 1 roles identified:

1. Model translators

2. Model software support tool technician

3. Liasion between application and logical layer to support natural language verification.

4. Data modelling expert who is able to verify equivalency of the computed form with the original application area reference models.

PHASE 2: Conceptualization and Integration

Goal: To build the conceptual schema and maximize its potential as a central resource in the PDES Initiation Effort and to develop a conceptual dictionary tool to hold the components of a conceptual architecture.

Input: Qualified binary models of the application areas.

Deliverable: A computerized conceptual schema in binary form, and a computerized data dictionary containing the conceptual architecture and conceptual-to-application area mappings.

Description: It is in this phase that the actual conceptualization and integration occurs. The reader is encouraged to refer to Appendix A which is an excerpt from "The Second PDES Report". It overviews and describes the three layer architecture. This phase is the most challenging of the three phases of the logical layer methodology. It is from this phase that the crucial aspects of extensibility, stability, resilience, and technology independence will be confronted. Some cultural resistance to this phase is to be expected as it seems to draw out the process of getting to the ultimate PDES deliverable, the physical file format.

As an initiating effort, this phase will start with popular concepts and notions of conceptual schema that have been derived from ANSI/X3/SPARC, ISO/TC97/SC5/WG3, NASA IPAD, and PDDI. The logical layer team realizes that conceptualization across the broad spectrum of product data represented in the application models is a new area for standards work. The team also realizes that the conceptualization of engineering and manufacturing artifacts is fairly new. The team expects to adapt the principles of conceptualization as they apply to business systems to engineering and manufacturing artifacts as much as possible, but realizes that new conceptualization principles must be developed.

PHASE 2 is divided into two sub-phases, PHASE 2A and PHASE 2B. PHASE 2A is concerned with the building of the conceptual schema from detailed application area reference models (in a general sense a bottom-up process). PHASE 2B deals with a conceptual schema architecture that will give high-level structure for the guidance of PHASE 2A activities (in a general sense a top-down process). It is anticipated that the software support tools for PHASE 2A and 2B will be separate but manually coordinated. The primary support tool for PHASE 2A will be IAST. The primary support tool for PHASE 2B may possibly be a relational data base system such as RIM.

PHASE 2A Description: The construction of a conceptual schema is not a well-defined process and this methodology will serve only as a guide.

The following tasks are identified:

1. Develop a set of entity categories. To the greatest extent possible these categories will be generic in that they may be used across a broad set of applications. These categories can be discovered as the qualified application reference models are being reviewed (bottom-up) or an initial set can be adopted provisionally from other sources such as PDDI.

2. Develop a set of structural categories. A structure in this case is a recognizable pattern of inter-related entities that appears in multiple application area models. The conceptual schema will consist of generic entities, generic structures, and application specific structures.

3. Examine each qualified application area model and attempt to break it completely into generic entities, generic structures, and application specific entities. This partitioning of the application area model is recorded in the data dictionary (this tool is created by PHASE 2B activities.).

4. Once the application area model has been completely translated into the conceptual schema, logical layer workers in conjunction with application layer workers verify that the original application area model can be recovered. It is the job of the logical layer worker to be familiar with the generic entitiies and structures. It is the job of the application area worker to find a best fit for his application entities. A cooperation effort between logical and application workers is crucial in this task.

5. Once the application area model is verified to be recoverable from the conceptual schema all mappings must be defined and recorded in the dictionary. The logical layer team may possibly not be concerned in the Initiation Effort about formally defining these mappings although in future PDES efforts it will become more important. In this case narrative sentences may suffice.

6. Make any adjustments to the conceptual schema (hopefully an addition of a new generic entity, not a change to an existing generic entity). It may be necessary to regressively test all previous application area models for recoverability after a major change to the conceptual schema.

PHASE 2B Description: This activity is similar to the strategic data planning activity for the development of a large integrated business information system. The tasks are as follows:

1. Adopt a conceptual schema architecture. Appendix B is an excerpt from the US position paper "Reference Models, Development Methodology, and Entity Subsets for STEP" submitted to ISO/TC184/SC4/WG. The subsets referred to in this paper are the major architectural components we are looking for. These architectural components will be dictionary categories. Refer to Appendix B for a complete rationalization for the need of a conceptual schema architecture.

2. Develop a conceptual dictionary tool to hold the architectural components. It would be advantageous if this dictionary were an integral part of the IAST but the PDES Initiation Effort delivery schedules will not permit this. It is suggested that a simple relational tool such as RIM be used provisionally. The following dictionary categories would be a start: Life Cycle Stage, Discipline, Functional Area, Application Area, Class, Entity, Version. This initial set of categories should greatly assist in giving the conceptual schema development project direction and cohesiveness. An effort should be made to keep the number of dictionary categories as small as possible. Obviously new categories must be added to cover the mapping of the conceptual schema to application area models.

PHASE 2 roles identified:

1. Model software support tool technician

2. Liason between application layer and logical layer

3. Dictionary administrator

4. Conceptual model administrator

5. Data architect who has broad knowledge of engineering and manufacturing life cycle, disciplines, and applications.

6. Data analyst

PHASE 3: Post-Conceptualization

Goal: To condition the conceptual schema in preparation for conversion to the PDES exchange format.

Input: The binary conceptual schema and mappings to application area models.

Deliverable: A complete specification of the conceptual schema in Data Specification Language (DSL).

PHASE 3 Description: The purpose of this phase is to convert the binary conceptual schema into a grouped logical record form (a structural form). This form is still neutral as it has not yet been committed to a physical form. The Data Specification Language (DSL) has been chosen as the PDES

Initiation Effort standard structural form. It was chosen because its form (nested array) naturally models the hierarchical structure of most engineering and maunfacturing artifacts. It is also a compact textual form suitable for documentation.

The major task is the actual conversion of the binary conceptual schema into DSL. For the PDES Initiation Effort this will be done manually but it is suggested for follow on efforts that this conversion be automated.

The DSL specification of the conceptual schema represents the official documentation, however the binary conceptual schema will always be the source from which the DSL specification is generated. The binary conceptual schema is the principle resource for the Initiation Effort.

PHASE 3 role identified:

1. Translator from binary conceptual schema to DSL

Appendix A

4.4 THE ARCHITECTURE OF THE PDES

The task of developing a data standard for industries using CAD/CAM is a huge undertaking. The problem must be broken down into smaller pieces in order to make progress. Modularization is the separation of a process into small, separate functions with precise interfaces between the functions. This separation makes each function manageable and eases maintenance since changes can be isolated to a specific function. Modularization provides flexibility to make changes since, as long as the interface between functions remains the same, one function cannot tell if another has been changed or even replaced. Modularization of the development process is a philosophy recommended for the PDES development. That is, different groups will be tasked with different functions of the design process. The function of data analysis and design will be partitioned into three parts based on the level of abstraction of the data. Thus, the application information will be separated from the conceptual entity definition which will be separated from the physical definition. Each such partition will be called a layer.

As alluded to above, the PDES will be structured into a three layer architecture. These layers correspond almost identically with the layers of schema in the ANSI/X3/SPARC *three schema architecture (cf. appendix* C.1.1) for defining and implementing data bases. The layers are described in the following sections and illustrated by figure 4-3.

4.4.1 Application/User Layer

In the chosen architecture, the top layer is the user or application layer. This is the layer at which the ultimate user lives and thinks. He formulates his data requirements in his own terms stating concisely what he needs. He draws from his own experience and from the established terms, conventions, techniques, and methodologies of his discipline. He isn't concerned with the number of different ways that a single thing, event, or phenomenon can be represented. He isn't concerned with analogous notions used by different applications. For example, he doesn't care that electrical

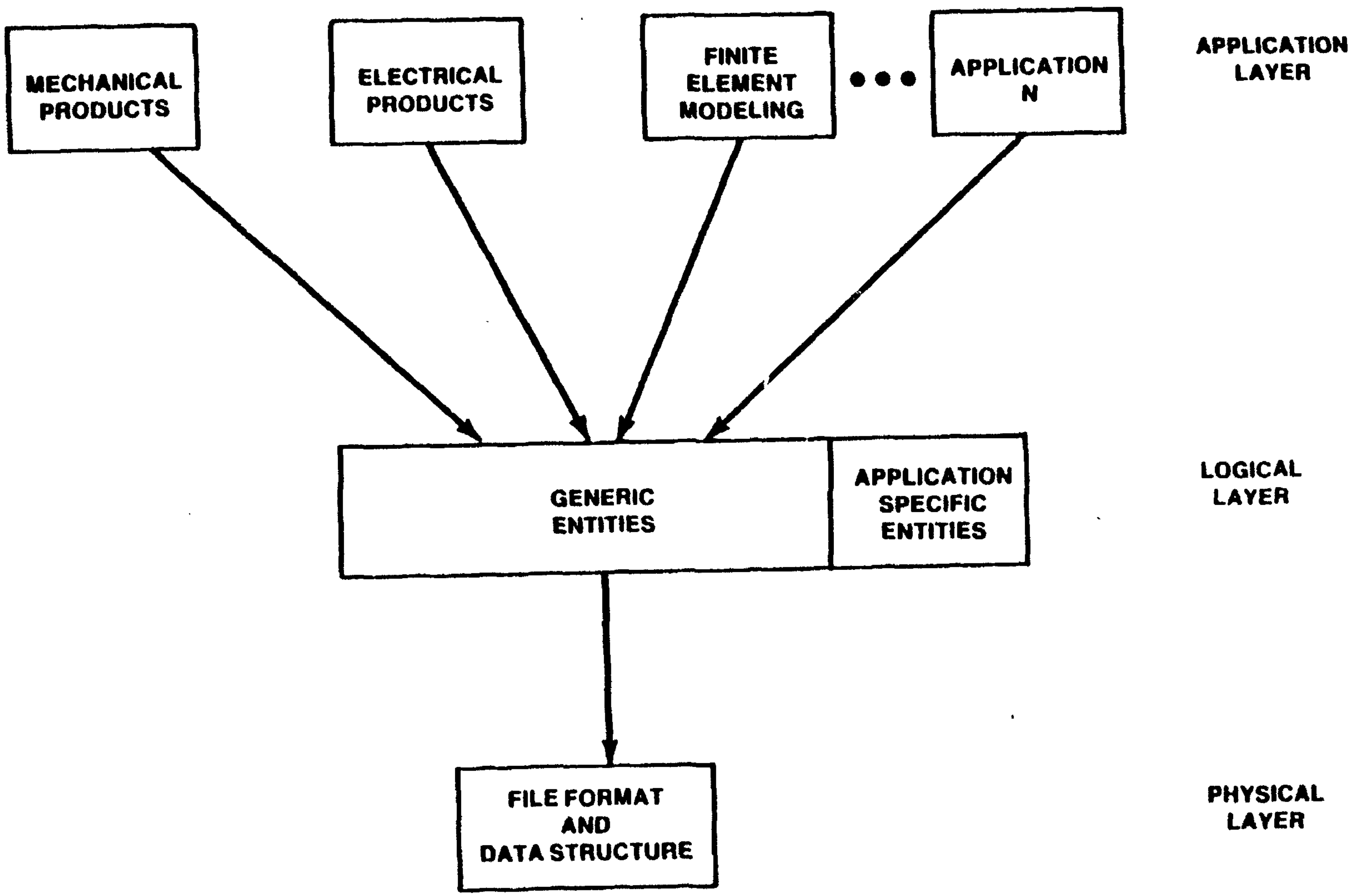


Figure 4-3. Three Layer PDES Architecture

and piping networks share much in common. The different application groups such as Electrical Products or Finite Element Modeling define the information relevant to their application and model the interrelationships that exist between the informational entities. This information is defined by using a reference or information model. The reference model helps structure and validate the data in the application.

This layer of the Standard contains as many different applications and entities within those applications as there is apparent need for.

4.4.2 Logical/Conceptual Layer

The second layer is the logical or conceptual layer. This is where the data content for the set of generic entities is defined. This set should be a normalized, minimumly redundant set (cf. sec. 4.3) that supports the information defined by the applications.

At this layer, logical commonality will be sought across all applications. Things, events, and phenomena which are identical except for the renaming of components will be treated as being logically identical. Thus the connectivity of a piping network and an electrical network will be considered logically identical. Also at this layer, there will be exactly one way, not several, to represent a directed line segment, perhaps by a point together with a direction vector.

At this layer, complex things, events, and phenomena will be constructed of less complex things, events, and phenomena whenever possible. The purpose is to maximize the utilization of conversion processors for simpler entities in the process of converting a complex entity.

Similarities in the information requirements of different applications will be integrated into single conceptual entities. The integration of different application requirements will control the definition of redundant entities and will help to ensure a consistent, coherent entity set.

The entity definitions at this layer will be in a logical form. That is, the data content of an entity will be defined but not the physical format. As described in Section 4.2, a definition language will be defined in which the entities will be specified. This language will be a formal, rigorous language which will help reduce ambiguity as is present in the IGES. In addition, reference models will be built to verify consistency among the definitions.

The data content of the set of application-specific entities will also be defined at this layer. These entities will be defined in the same rigorous manner as the generic entities above, that is with their data content specified using a formal definition language and reference models.

It is expected that the concepts of the logical layer will be organized as the product data itself is organized. This organization is discussed in section 2.1 and is outlined in figure 2-1.

4.4.3 Physical/Internal Layer

The bottom layer is the physical or internal layer. This layer contains one or more actual file format definitions. It consists of the description of the sections, records, fields, sequencing, and associated formats for the exchange file. Again, a formal definition language will be used to reduce ambiguity. A reference model will be built for each format definition.

Since the content is separated from the format, multiple formats can be defined for logical entity definitions which only affect the read/write routines of a processor. Thus the majority of a PDES processor will be independent of the file format.

Appendix B

APPENDIX B

6.0 Subsets of the Conceptual Schema

One or more mechanisms are required within the Conceptual Schema for defining subsets of entities. These will be used in a variety of ways for creating, understanding and using STEP.

6.1 Requirements for Subsets

6.1.1 Human Understanding of the Standard

- To understand any large collection of facts (such as the Conceptual Schema), a human must categorize the facts into collections (subsets) which are intellectually manageable.

- o The names on the subsets can be used to understand the scope of the collection.

- o Subsets for the Conceptual Schema act as a directory for users or logical modelers (developers) to find existing entities that perform a function.

- o An entity can be better understood if other members of its subset and the nature of the subset are known.

- o Users can match an application with others which can do the same or related jobs based upon Conceptual Schema subsets.

6.1.2 Functional Requirements

- o Subsets provide an abbreviation efficiency within the reference models. For example, when a certain attribute may be any valid curve, we can specify the class "CURVE" rather than enumerating all valid curves.

- o Schema management procedures may be used to propagate common attributes to every member of a class.

- o Subsets can be used by validation checking software to certify translators and other applications.

6.1.3 Management of Development

- o Subsets of the Conceptual Schema represent subsets of the work required in developing the standard. They can be used to define the scope, development milestones, and subdivision of labor and expertise.

- o A uniform system of subsets may be useful in recognizing voids in the standard. For example, if analysis reference models had been defined for mechanical and architectural disciplines, but not for electrical, the void would be obvious.

o Versions of the standard could be regarded as natural, time-dependent, subsets.

6.2 Identification of Subsets

The best method of subset identification would be to exercise the methodology discussed in Section 4 and use logical layer processing to help discover natural functional subsets. However, logical layer processing would be enhanced by a pre-existing, coordinated set of subsets selected from common knowledge of data, functions, and applications within the CAD/CAM community. This set will undergo continual review and updating as the standard develops in the logical layer deliberation.

6.3 Proposed Subset Types of the Conceptual Schema

To address all of the above, a network of subsets of several types are required. The structural relationships between the types is depicted in Figure 3. The types are defined as follows:

Versions - Time sequenced sets of the entire standard. Each version would contain all entities and subset structures valid in a particular release of the standard.

Functional Area - A high level set of application area subsets can be used for a particular function. It can be regarded as a two dimensional matrix of engineering disciplines and product life cycle as shown in Figure 4. Each cell on the matrix defines a functional area and may contain multiple application area subsets. This chart and concept is adapted from document (4). In that document the matrix is part of a 4 dimensional matrix called "Level". The term "Level" derived primarily from another dimension which classified geometric complexity. That concept is part of a following class structure.

Subset Types in the Conceptual Schema
As Related to Entities

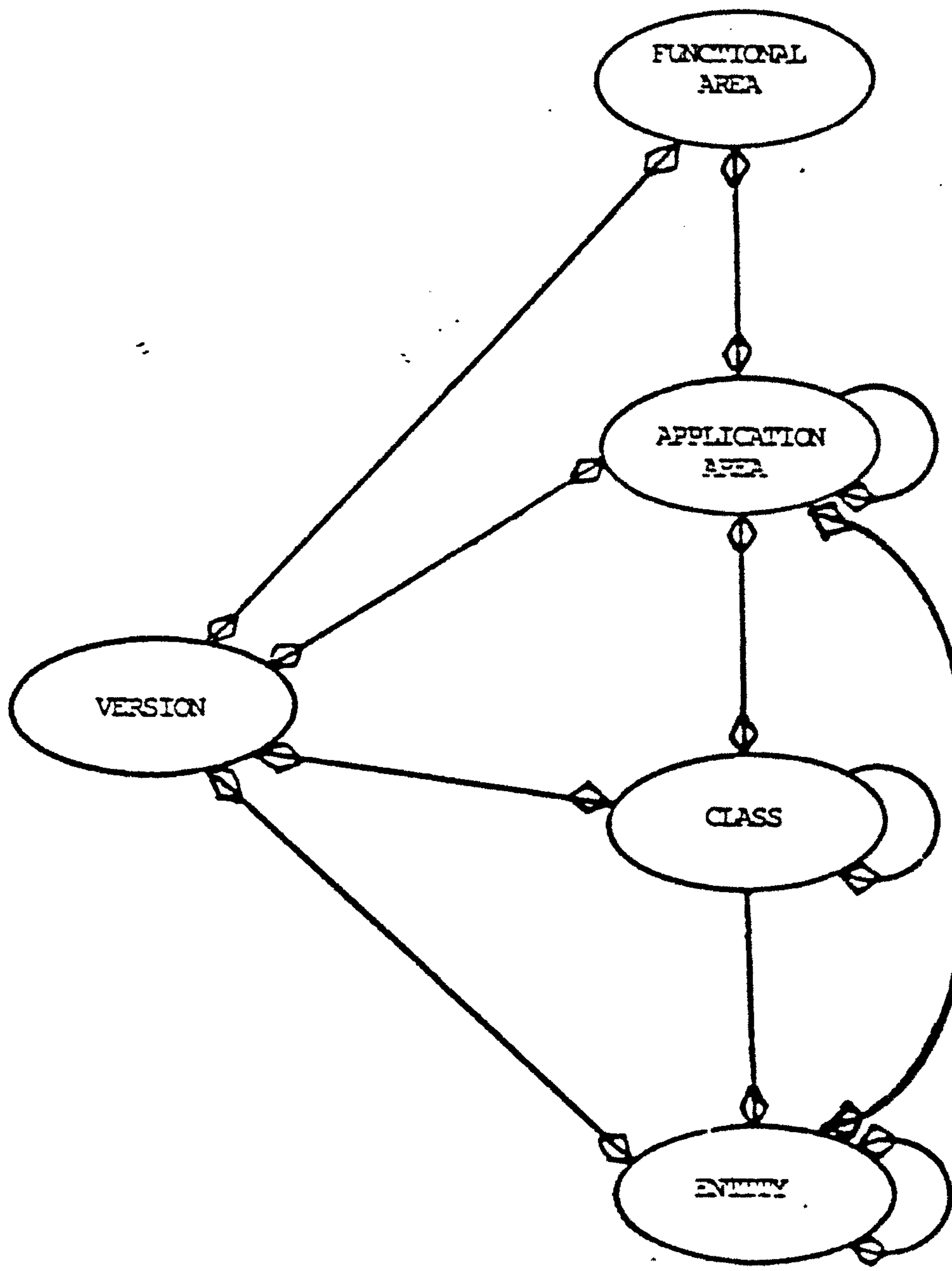


FIGURE 3

FUNCTIONAL AREAS

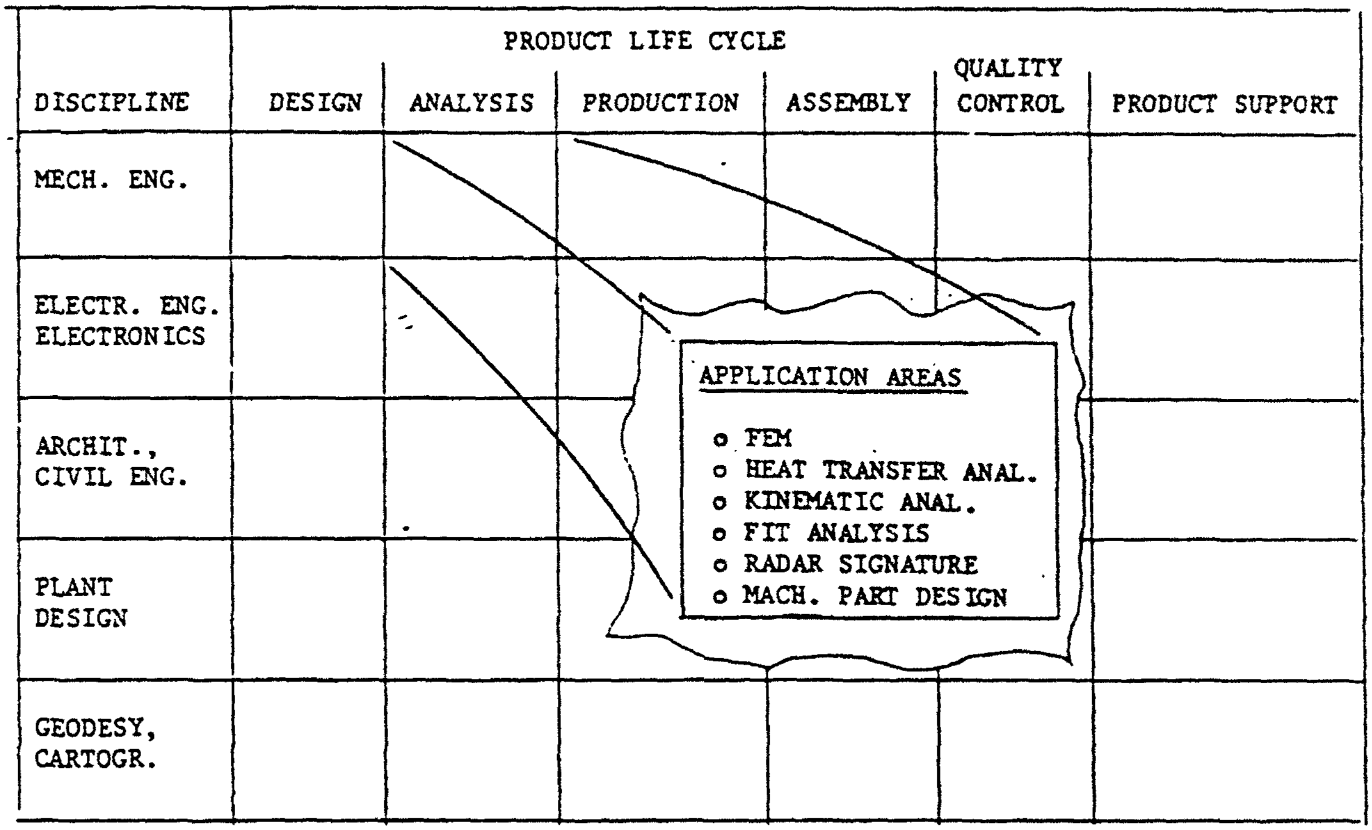


FIGURE 4

Application Area - A set of entities and classes for modeling the concepts of a particular application (such as forging design) or related applications (such as forging design and manufacture). Application area subsets may apply to multiple Functional Areas; e.g. FEM Application Area will be used for analysis in several disciplines. An application area may contain other application areas; e.g., manufacturing forging area may be different from but may include design forging area. A combination of version and application area could be used to specify capability of an application.

Class - A set of entities or classes (but not both) which are semanticly similar. Each entity is contained in exactly one class. Each class is contained in zero or one higher level class.

A class may be generic or application area specific. This means it may be used in multiple application areas or may simply collect the entities which are unique to a single application area.

In Figure 3 the relations between subset types and entities are represented as single diamond leaders for one-to-many relations and double diamond leaders for many-to-many relations.

See Appendix B for the recommended classes and entities for STEP.

6.4 *Storing Subset Definitions*

One method for defining subsets within the conceptual schema is the "class" structure defined in the Data Specification Language in WG1 N20. Additional methods may be required, particularly for versions.

STEP Classes

2.1.1 Geometry/Topology
2.1.2 Tolerance
2.1.3 Form Feature
2.1.4 Part/Assembly
2.1.5 Administrative & Control
2.1.6 Constraint Dependency
2.1.7 Material
2.1.8 Process
2.1.9 Instances

Generic Design Classes (Used by Multiple Life Cycle Stages)

2.2.1 Analysis
2.2.2 Manufacturing
- o Planning
- o Fabrication
- o Assembly

2.2.3 Quality Assurance
2.2.4 Testing
2.2.5 Product Support

Classes for Specific Stages of Product Life Cycles OR Specific Application Areas

2.3.1 Product Manifestation
- o Documentation
  - o Drafting
  - o Bill of Materials
- o
- o Display

2.3.2 Metadata
2.3.3 Parametric Design
2.3.4 Data Base
2.3.5 User Defined Entities

Appendix B

Figure 1

STEP Classes

2.1.1 Geometry/Topology
2.1.2 Tolerance
2.1.3 Form Feature
2.1.4 Part/Assembly
2.1.5 Administrative & Control
2.1.6 Constraint Dependency
2.1.7 Material
2.1.8 Process
2.1.9 Instances

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Appendix B

Figure 1